MARCH 1957

THE WELDING JOURNAL

1957 WELDING SHOW
AND ADAMS NATIONAL MEETING

Flame Washing of Steel Castings 219
Rockets for Steel Hardening 225
Inert-Gas Welding of Zircaloy-2 Tubes . . 230
Course in Welded Rigid Frame Design . . . 236
Joint Design for Root-Pass Welds 240
Peripheral Welding of Internally-Clad Steel . 243
Acceptance of Welding Through Inspection . 252
Effect of Irradiation on Weldability of A212 . 105-s
Comparative Study of Tungsten Electrodes . 113-s
Effect of Plastic Fatigue on Pressure Vessels 120-s
Brazing Thin Sections of Stainless Steel . . 131-s
Service Performance of Austenitic Welds . 141-s
Fundamental Concepts of Oxygen Cutting . 151-s
Weldability of Pressure-Vessel Steels . . 157-s
Table of Contents 215
Editorial 217
Adams National Meeting Program . . . 272
Index to Advertisers 338

SPECIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY

QUALITY JACKSON PRODUCTS

New 'Quik-Trik' Cable Connectors by Jackson

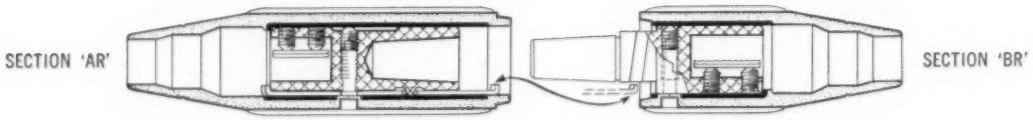
New Neoprene rubber insulators, strongly built around steel sleeves, have tapered ends to stretch over the welding cable snugly. They lock out moisture, oil and dirt, don't catch against obstructions.

Economical to install. No capital equipment is needed, no time consuming vulcanizing. Simply loosen an Allen screw, slide off the insulator and slip it over the cable end. Then connect the cable as usual, either mechanically or by soldering or brazing. Slide back the insulator and tighten.

Model 2/0-R, as illustrated, takes cables 1/0 and 2/0, mechanical, soldered or brazed connection.

Model 4/0-R takes cables 3/0 and 4/0, soldered or brazed connection only.

Section BR (male) of model 2/0-R can be used with section AR (female) of model 4/0-R where the use of different sizes of cables may be desired.



Really 'Quik-Trik'

For a quickly detachable connection, there never was a better metal-to-metal contact than is provided by these smoothly machined tapers drawn tightly together. And now, these new Neoprene insulators are tapered together in the same way. With a twist of the hand, a steel locking bar rides a cam to lock the sections together.

Always fasten section AR (female) to the cable leading from the machine. The live cable end is then well insulated even when detached from section BR (male).

The new Neoprene insulators are recommended for use with the 2/0 and 4/0 Quik-Trik Connectors now in service.

CHECK NOW. Look over your welding cables for costly current leaks and makeshift connections. You'll be money ahead by having Jackson's Ground Clamps, Cable Connectors, Splicers and Lugs stand guard against power losses and accidents all along your cable lines.

Jackson Products

AIR REDUCTION SALES CO., A DIVISION OF AIR REDUCTION CO., INC.

WARREN • MICHIGAN

Check *the MANY WAYS you can CUT COSTS with Hobart Welders!*

AC/DC WELDER COMBINATION

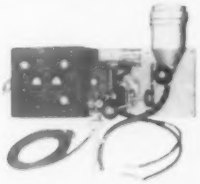
New Convenience – many built-in extras, such as remote control and fast acting polarity switch – at no extra cost – that's the story of Hobart Welders.

It's the extra features that help to lower your operating costs and realize more profit on production, maintenance, construction and general repair work. Versatility is another Hobart byword.

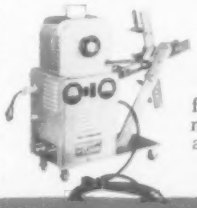
For instance, the brand new Hobart AC-DC Welder lets you take full advantage of the latest types of electrodes and sizes for both AC and DC welding. In addition to having AC or DC welding, you'll want to see and know about variations of this welder that let you do Inert Gas Welding.

Hobart Welders will amaze you with their wide welding range and top performance. To compare is to be convinced. And Hobart has a complete line of welders, so that you can select the right size and type welder to handle your particular work.

Phone or write now for complete specifications, prices, or any other information, to HOBART BROTHERS COMPANY, BOX WJ-37, TROY, OHIO, Phone FEderal 2-1223.



FULLY AUTOMATIC
submerged arc welding with new "simplified" controls



HANDOMATIC
for semi-automatic submerged arc welding

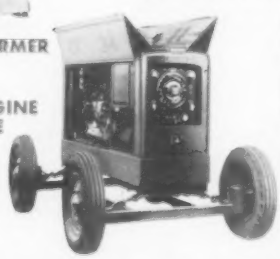
"Simplified Control Automatic Welding"

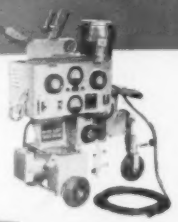
Eliminates complicated electronic controls. Even less experienced welders can double output and produce uniform high quality welds.

DC RECTIFIER

C TRANSFORMER

GAS ENGINE DRIVE





TRACTOR TYPE
for submerged arc welding

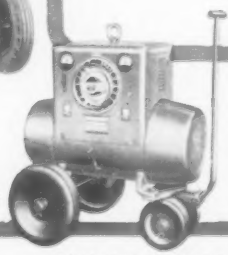
POWROMATIC
for automatic arc welding

See demonstrations

of these amazing new welders

WESTERN METALS SHOW
Los Angeles — March 25-29
BOOTH #650

A.W.S. SHOW
Philadelphia — April 9-10-11
BOOTH #100

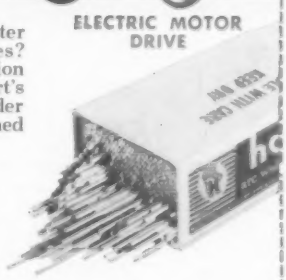


ELECTRIC MOTOR DRIVE

Hobart
" one of the world's largest builders of arc welding equipment "

HOBART TROY OHIO WELDERS

Have you tried the new and faster Hobart Iron Power Electrodes? Keep pace with faster production and lower cost welding. Hobart's "Rocket 24" hi-speed iron powder electrodes are especially designed for using the "drag" technique. Deposition rate is much higher than conventional type electrodes. Beads are smooth. Slag is practically self removing. Get more inches of weld per electrode. For proof —try a few "Rocket 24" electrodes on your own work.



HOBART BROTHERS COMPANY, Box WJ-37, TROY, OHIO

Without obligation, send complete information on:

_____ampere capacity

- ☐ AC/DC Welder Combination
- ☐ DC Rectifier
- ☐ AC Transformer
- ☐ Gas Engine Drive
- ☐ Electric Motor Drive
- ☐ Fully Automatic
- ☐ Handomatic
- ☐ Tractor Type
- ☐ "Powromatic"
- ☐ Iron Powder Electrodes

Name_____

Address_____

City_____ State_____

this finer cutting torch

multiple mixer in torch head... it offers greater safety and greater efficiency...

A cutting torch mixer may be located either within the torch handle, the torch tubes or the torch head. When located within the handle or the tube, the mixer is situated in close proximity to the operator's hands; no torch, however, need be held by its head.

And, besides, there is plenty of metal in that torch head to permit for an added advantage: Multiple Mixing. By breaking up the streams of the low pressure oxygen as well as the fuel gas into several separate channels, the port diameters are lessened, thus offering greater flash-back resistance.

This modern, patented, Multiple Mixing in the torch head is costlier to manufacture but it eliminates the need for a separate mixer, leaky seats and joints, and years of experience in shop and field have proved the outstanding excellence of this patented design feature.

the mixer is located where it works best...and is safe.

is made by

National of ...california

NATIONAL welding equipment company... 218 fremont street san francisco 5 california

534

Welding Output Increased

on Western Electric Coin Box Production

In Canada, made and sold by Johnson Matthey and Mallory, Ltd., 110 Industry Street, Toronto 15, Ontario

Serving Industry with These Products:

Electromechanical—Resistors • Switches • Tuning Devices • Vibrators
Electrochemical—Capacitors • Rectifiers • Mercury Batteries
Metallurgical—Contacts • Special Metals • Welding Materials

Suppose you needed to spot-weld sheet steel to steel forgings, in hard-to-reach locations. Western Electric's plant at Indianapolis had this problem on telephone coin boxes. Custom-designed electrodes and holders had seemed the way to do the job.

But, since using a standard Mallory heavy-duty offset holder and Mallory bent tips, their welding costs have been reduced and production rate has been increased.

Output increased. The number of parts welded per shift has been increased significantly. Reason: less tip dressing, less setup time loss, cooler operation and minimum respotting.

Longer electrode life. Replacement rate is now less. Reason: better cooling of electrodes . . . all the way to the tip.

Less down time. Re-dressing is now needed only once per shift.

Chances are that you, too, can make substantial savings in resistance welding production, by using Mallory electrodes, holders, seam welding wheels, dies, castings and forgings . . . and by taking advantage of Mallory engineering service in applying these products effectively to your problem. See your local Mallory welding distributor for prompt service, and write to us for our resistance welding catalog.

Expect more . . . Get more from

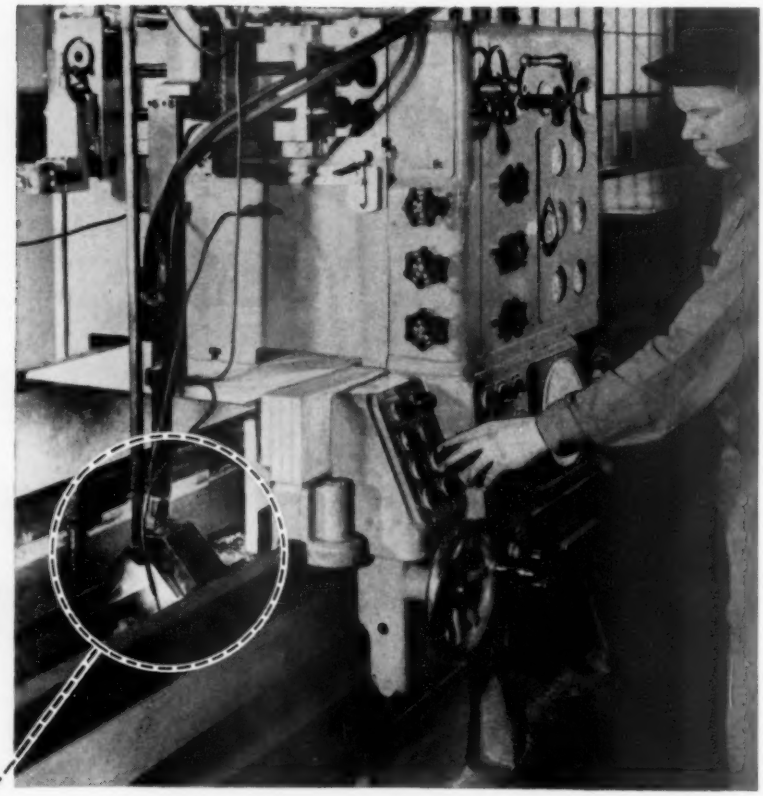
P. R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

HIGH SPEED FLAME-HARDENING



Cross-section view shows uniform depth of hardened surface.

SPECIAL MACHINE UPS LIFE OF GRAPHITIC STEEL PARTS

LINDE engineers have assisted Cincinnati Steel Treating Company in developing a flame hardening machine which increases service life of 16 ft. long, graphitic carbon steel lathe ways . . . Development of this automatic, high speed machine is another example of how LINDE Service Engineers are helping LINDE's customers up production speed and unit quality through co-operative research engineering.

With this new machine, a lathe way to be treated is placed on a magnetic chuck in a water filled channel. Flame-hardening heads and control mechanism move at predetermined speeds along the part. After it cools, the lathe way is placed in a refrigerator for 24 hours which stabilizes the steel, and brings its case hardness to a minimum of 60 Rockwell "C" scale.

The benefits of LINDE's research, engineering, and over 40 years of accumulated know-how stand behind each of its customers to help them solve production problems. Get these "plus-values" which LINDE offers—it pays you to do business with LINDE.

Linde Air Products Company
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
Offices in Other Principal Cities
In Canada: LINDE AIR PRODUCTS COMPANY
Division of Union Carbide Canada Limited, Toronto

The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

Linde
Trade-Mark

THE WELDING JOURNAL

VOLUME 36 • NUMBER 3 MARCH 1957

TECHNICAL PAPERS, ITEMS AND REPORTS

Editorial—*The Beginning . . . Comfort A. Adams, by Boniface E. Rossi* 216, 217
Flame Washing of Steel Castings, by A. F. Chouinard 219
Rockets for Steel Hardening, by James A. Browning 225
Inert-Gas Tungsten-Arc Butt Welding of Zircaloy-2 Tubes, by J. W. Lingafelter 230
A Short Course in Welded Rigid Frame Design, by Martin P. Korn 236
Joint Design for Making Root-Pass Welds Without Filler Metal, by L. C. Lemon and W. R. Smith 240
Peripheral Welding of Internally-Clad Steel for Nuclear Reactor Application, by W. Leonard and J. C. Thompson, Jr. 243
Greater Acceptance of Welding Through the Use of Inspection Methods, by John R. Harrer 252
Editorial Previews—*World's Heaviest Unit of Atomic Power Equipment Built for Shippingport* 269

PRACTICAL WELDER AND DESIGNER

Welding All-Aluminum Superstructures for U. S. Navy Destroyers, by Ralph Bradway and C. G. Serroi 257
Automatic Welding Processes Boost Production of Hot-Water Heaters 259
Aluminum Covers Protect High-Tension Bus Bars 260
Modern Welding Procedures Speed Completion of 290-ft Oil Barge, by Donald Hastings 261
Rotary Drum Stores Pre-Mixed Flux for Brazing Operation 262
Fast Fabrication of Fire Bombs, by Larry Kunkler 263
Iron-Powder Electrode Effectively Used in Fabricating Turnpike Expansion Joints, by Robert Hall 264
Mechanized Oxygen Cutting Contributes to Accelerated Production of Turbine Generators, by J. F. Buerkel 266
Carrier Elevator Is Largest All-Welded Aluminum Structure in USA 268

SOCIETY AND RELATED EVENTS

Society News 271
Technical Papers Sessions—1957 AWS Adams National Meeting and AIEE Electric Welding Conference 272
Highlights of Exhibits at 1957 Welding Show 278
Section News and Events 286
New Members 306
Employment Service Bulletin 308
Current Welding Literature 310
Abstracts of Current Patents 312
News of the Industry 314
Personnel 326
New Products 332
New Literature 337
Index to Advertisers 338

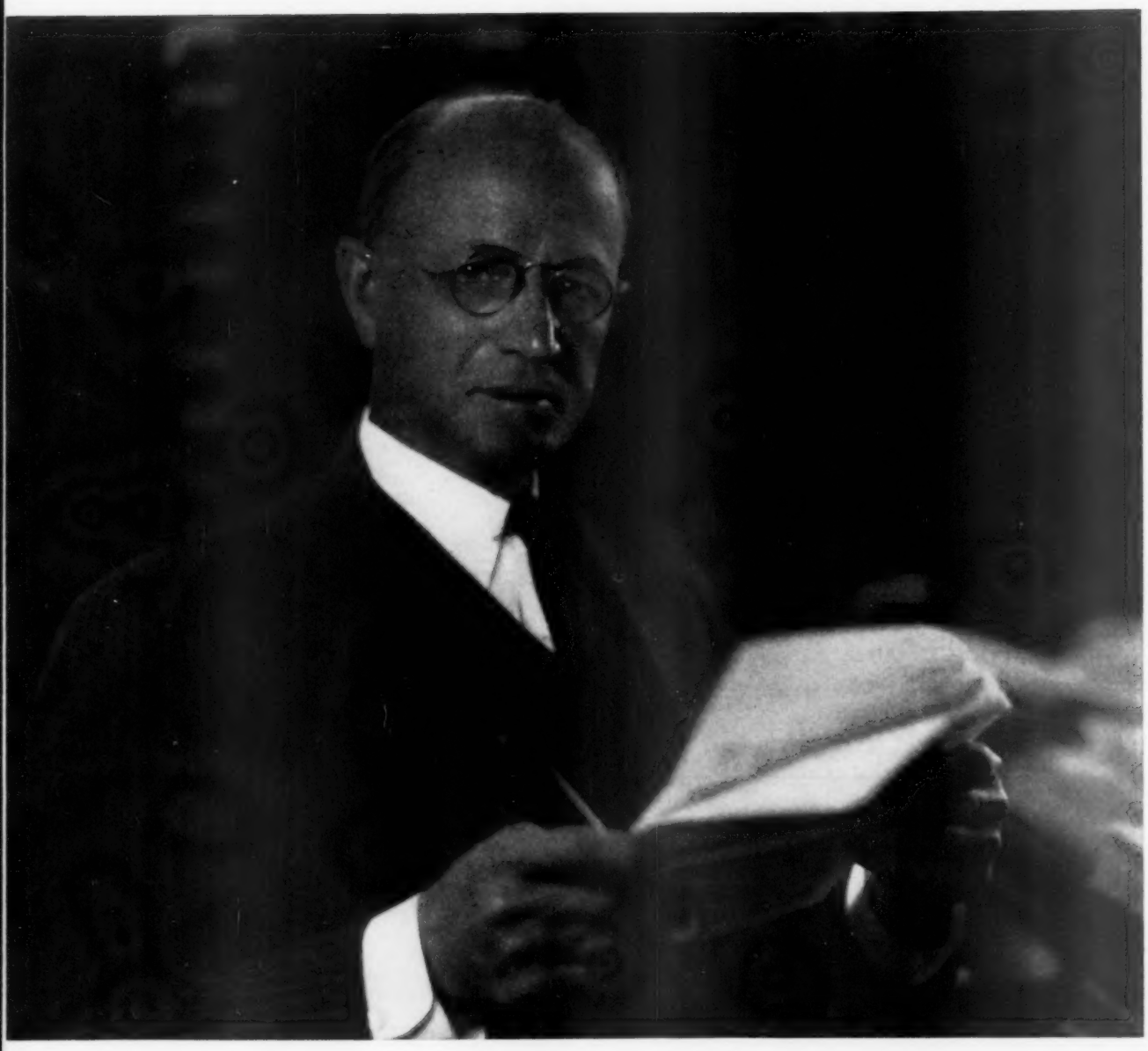
WELDING RESEARCH SUPPLEMENT

Effect of Irradiation on Weldability of ASTM A212, Grade B, by Wendell R. Hutchinson 105-s
A Comparative Study of Thoriated, Zirconiated and Pure Tungsten Electrodes, by L. P. Winsor and R. R. Turk 113-s
Effect of Plastic Fatigue on Pressure-Vessel Materials and Design, by L. F. Kooistra 120-s
Alloys for Brazing Thin Sections of Stainless Steel, by A. S. McDonald 131-s
Ductility Related to Service Performance of Heavy-Wall Austenitic Welds, by Henry M. Soldan and Charles R. Mayne 141-s
Papers at the Fourth Czechoslovakian Welding Conference, 1954 . . . . . 150-s
Fundamental Concepts of Oxygen Cutting, by R. L. Stoecker and W. B. Moen 151-s
Properties and Weldability of High-Strength Pressure-Vessel Steels in Heavy Sections, by J. H. Gross and R. D. Stout 157-s

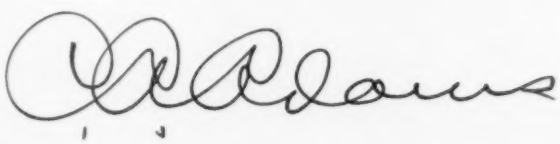
Published for the advancement of the science and art of welding by the American Welding Society

Published monthly by the American Welding Society. Publication office, 20th and Northampton Streets, Easton, Pa. Editorial and general offices, 33 West 39th St., New York 18, N. Y. Subscriptions $7.00 per year in the United States and possessions; foreign countries $8.50. Single copies, nonmembers $1.00; members 75 cents. Entered as second-class matter January 5, 1932, at the Post Office at Easton, Pa., under the act of March 3, 1879.

Copyright 1957, by the American Welding Society. The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication provided credit is given.



SCIENTIST . . . HUMANITARIAN . . . AWS FOUNDER



EDITORIAL

The Beginning . . . Comfort A. Adams

In these days when we are so busy making ambitious plans for the future of welding, how many of us realize that the building of a wholly welded ship was first authorized some forty years ago?

At the time that the United States entered World War I in 1917, there was a great rush for the mobilization of our military forces and agencies, together with numerous civilian organizations including the new Council of National Defense and its subsidiaries. One of these was the General Engineering Committee made up chiefly of presidents and past presidents of the engineering societies. Shortly after the organization of this Committee, Comfort Avery Adams was elected as its chairman. Since accelerated shipbuilding was vital to the welfare of our nation, and since many were convinced that welding could be applied effectively in this field, the Emergency Fleet Corp. organized a Welding Committee under the chairmanship of the same Dr. Adams.

In addition to sponsoring a number of elementary research projects, this Committee was called upon to guide the application of welding to the emergency shipbuilding. Although this activity involved only minor ship elements, it saved the government millions of dollars.

What is more important, the potentialities of the new metal-joining process so impressed the members of the Emergency Fleet Corp. that they approved a proposal by the Welding Committee for the building of an all-welded ship. These plans were tabled immediately after the Armistice, but the hearty cooperation established between the corporations interested in welding not only lived on, but actually grew stronger.

After the war, there was a general urge for the continuance of this cordial cooperation through the medium of a welding society. As a result, AWS was organized in April 1919, just thirty-eight years ago, with an initial membership of about 200—Dr. Adams was made its first president. Today, our SOCIETY has a membership of nearly 12,000; Dr. Adams, now eighty-eight years old, is its oldest living past-president.

The welding process includes many sciences and nearly all branches of engineering. Fortunately for AWS, Dr. Adams had all the necessary qualifications to meet the challenge ahead. His knowledge of the underlying scientific laws, his familiarity of the appalling complexities involved, his awareness of the need for further research and his full appreciation of the practical aspects, founded a sound endeavor which was destined to develop into the most vital element of the modern metal-fabricating industry.

Our debt to the founder of our SOCIETY has no bounds—the best way to show our gratitude is to keep ever alive his faith in things of welding, his unwavering strength in the face of difficult problems, his keen perspicacity and foresight, his constant exhortation for cooperation and his great humanitarianism.

Boniface E. Rossi, Editor
The Welding Journal

THE
WELDING
JOURNAL

Editor
B. E. Rossi

Assistant Editor, Production
Catherine O'Leary

Officers of the Society

J. J. Chyle
President
C. P. Sander
1st Vice-President
G. O. Hoglund
2nd Vice-President
R. S. Donald
Treasurer
J. G. Magrath
Secretary
F. J. Mooney
Asst. Secretary
S. A. Greenberg
Technical Secretary

Welding Journal Committee

O. B. J. Fraser
Chairman
E. J. Tangerman
Vice-Chairman

H. R. Clauser
John Haydock
C. L. Helms
C. G. Herbruck
John McCracken
J. E. Norcross
A. G. Oehler
G. W. Place
A. V. Scherer

the NEW miller MULTI ARC combination ac-dc welder

The Miller Multi-Arc combination ac-dc welder, built specifically for metallic arc welding, delivers either ac or dc current at the flick of a switch. Electrical control circuit eliminates mechanical controls. Primary switch is standard equipment; Power Factor Correction optional. Six models from 10 to 525 amperes—all with 60% duty cycle ratings.

Complete specifications sent on request.

". . . If it's Miller you know it's the finest . . ."

miller Electric Manufacturing Company, Inc. APPLETON, WISCONSIN

distributed in Canada by CANADIAN LIQUID AIR CO., LTD., Montreal

Please visit Booth 422 during AWS Spring Meeting

Typical flame washing of castings

FLAME WASHING OF STEEL CASTINGS

Paper indicates that flame washing of steel castings with oxyacetylene flame saves time, cuts cleaning costs and helps to eliminate bottlenecks in cleaning room through better production control

BY A. F. CHOUINARD

SYNOPSIS. Flame washing offers progressive foundries these major benefits: (1) It can cut cleaning time of castings to one-quarter to one-third the original time. (2) Capital investment costs are lower for flame-washing equipment than for grinding equipment. (3) Flame washing reduces handling of castings. (4) It improves employee relations. (5) A flame washer can be trained quickly.

Flame washing can remove riser pads, fins, chill bars, reinforcing nails and core chaplets from steel castings. Riser pads may require one or two passes, depending on width or diameter of pads. Powder washing, with a special torch employing powder injection, can remove sand inclusions and sand penetrations far more rapidly than chipping and grinding.

A. F. Chouinard is Manager, Research and Development Department, National Cylinder Gas Co., Chicago, Ill.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

The flame-washing method is adaptable to all shapes and sizes of castings. Steel analysis may restrict its use but, as a rule, any casting that can be cut with an oxyacetylene cutting torch can be flame-washed. Some irons and high-alloy steels may require powder washing.

Techniques of flame washing are easy to learn. The washer should adjust gas pressures to suit pad size and casting-section thickness, operate torches at full volume of preheat gases and manipulate torches in an oscillating or elliptical pattern.

Introduction

Too many steel foundries are still doing it the hard, expensive way—removing risers, fins, pads and other excess metal from castings by the chipping hammer and the grinding wheel. On the other hand, more progressive foundries are turning to flame washing

with an oxyacetylene flame to save them time, cut cleaning costs and eliminate bottlenecks in the cleaning room through the better production control that is then possible.

Removing of excess metal, as well as sand inclusions, sand penetrations and burned-on core sand, has always been a major problem—and an expensive one. To finish some castings by older methods may cause cleaning-room costs to run as high as 35% of the total manufacturing cost; about one-third of this expense goes for chipping and grinding. So, flame washing was developed a few years ago to meet the demand for a better, cheaper way to remove excess or defective metal and to bring castings to a marketable condition without all the chipping and grinding previously necessary.

Gates, risers, etc., are first removed by an oxyacetylene cutting torch. This is fast but leaves pad surfaces comparatively rough (Fig. 1*a*). So in the older cleaning method some chipping and grinding (by hand or swing grinder) was still necessary. In the newer method, flame washing (Fig. 1*b*) replaces the chipping and grinding operations.

A major advantage of flame washing is the time saved in cleaning the castings. Some foundries have found that when chill bars and pads are located in positions difficult to grind, or when grinding a surface such as a contour takes from 15 to 20 min., flame washing can save time over grinding.

A flame-washing torch is far easier and faster to apply to hard-to-reach spots than even a hand grinder. If both chipping and grinding would be needed to clean up a casting, flame washing can cut the cleaning time to from one-quarter to one-third the original time.

Capital investment costs are lower for flame-washing equipment than for grinding equipment. To equip a foundry with grinders and a dust exhaust system requires an investment about ten times as great as that for flame-washing equipment. If the latter is installed, only a few hand grinders would be needed and all swing grinders and the exhaust system could be eliminated.

As flame washing removes pads and other excess metal on the shakeout floor, just after flame cutting of risers, castings need not be moved into the cleaning room. Instead, they go directly to shotblast or annealing, if either operation is to be done, and thus skip one handling operation. If production is not too high, one operator can do both cutting and washing by using two separate torches. Greater production would keep a man, or more, busy on each operation.

An additional advantage of flame washing, over and above the reduction in cleaning time and costs, is improved employee relations. Both chipping and swing grinding are strenuous jobs, and it has become increasingly difficult to employ men—and keep them—for such work because of the high noise level and vibration fatigue. Flame washing, on the contrary, does not require nearly so much physical effort and, with a 30-in.-long torch, does not subject the operator to excessive heat.

It is also easier to train a flame washer. A week's training can convert a good oxyacetylene cutter to a good flame washer. But at least three to four times as long is needed to train a chipper, to show him how to take care of his chisels, to get his production speed up to an acceptable level. And as much time is needed to train a grinder so he doesn't undercut the work or wear out wheels too rapidly.

Where Flame Washing Can Be Used

Riser pads, fins, chill bars, reinforcing nails and core chaplets make up most of the excess metal that

Fig. 1*a* Before: Riser and gates have been flame cut from the casting, leaving rough pad surfaces to be finished

Fig. 1*b* After: Two pads, top and right side, have been flame washed to provide smooth, even surfaces. The third pad, on the left side of the casting, is still to be washed

Fig. 2 The riser feeding this bell-shaped casting was removed by oxyacetylene torch (left). The remaining pad was then flame washed and blended evenly into the contour of the casting

must be removed from steel castings.

Riser pads, left from torch-cutting of gates and risers, can be flame-washed in one or more passes, depending on width or diameter of pad. A good operator can remove a pad (Figs. 2, 3 and 4) and blend the area in with the casting contour so evenly that it's hard to detect where the pad has been.

As smooth a job can be done with fins, at parting lines. But at times, so much sand may adhere to the base of a fin that ordinary flame washing may not provide enough heat to melt the sand without gouging the adjacent areas. A special flame-washing torch employing powder injection may then remove sand and fin more rapidly.

Chill rods and bars, which can be removed by rapping, may be flame-washed, especially if they are located in fairly inaccessible areas. Washing also removes nails and chaplets more rapidly than their shanks can be chipped off.

Particularly difficult to remove are sand inclusions and sand penetrations. Chipping and grinding out inclusions is a slow process as the sand is below the casting surface. Powder washing removes them quickly as the powder supplies molten iron oxide that floats out the sand particles. Powder washing is just as effective for sand penetrations and burned-on core sand. The latter may be especially difficult to remove by chipping as the hardened, tightly adhering sand may be in recesses almost impossible to reach by chipping hammer.

Flame washing is adaptable to all shapes and sizes of castings. The area that can be flame-washed in one pass is limited by surface heat and may require multiple passes.

Fig. 3 Another view of the same casting as in Fig. 2 shows a gate pad (bottom) before washing and (at top) the smooth surface left by flame washing a similar pad

Steel analysis may restrict its use because the heat of the process may cause the casting to crack. Trouble may be encountered with high-carbon castings—over 0.30% of carbon, although steel with up to 0.50%

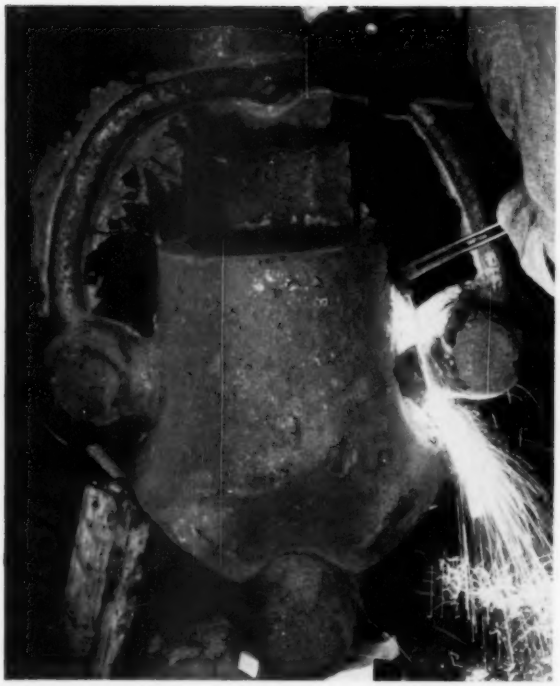


Fig. 4a First step in cleaning casting is removal of gates and risers from the casting by oxyacetylene torch

Fig. 4c Flame-washing torch is shown here washing off excess pad metal

Fig. 4b Three pads—top and sides—have to be removed to blend into the contours of the casting

Fig. 4d The flame-washed casting, with pad areas blending uniformly into casting contour, required no further finishing; the time—only two-thirds of that formerly required for grinding

carbon can be flame-washed without ill effects if washing is done immediately after shakeout while the casting is still hot.

As a rule, if a casting can be cut with an oxyacetylene cutting torch, it can be flame-washed. Some irons, stainless steel and high-alloy steel castings can be powder-washed.

Flame-Washing Techniques

The equipment needed for flame washing includes, besides the usual oxygen and acetylene cylinders and regulators—or means for central gas distribution, only flame-washing torches and tips. Torches are similar to standard oxyacetylene cutting torches, except for length—30 in. compared to the usual 21 in. for cutting torches. They are available with either 75° or 20° heads, the latter being particularly adaptable to flame washing of interior surfaces.

Recommended gas pressures for flame washing range from 12 to 15 psi for acetylene and from 65 to 95 psi for oxygen, depending on pad size and casting-section thickness. A higher gas pressure removes large pads more rapidly, but it is necessary to use lower pressures for thin-walled castings. The velocity of the washing oxygen must be high enough to carry away the molten metal without gouging below the contour of the casting and also to keep the tip cool.

Torches should be operated at full volume of preheat gases to obtain the same advantage of high-velocity gas as a coolant and thus keep tips cooler. At low gas velocity, tips overheat and, as a result, do not last nearly so long as tips operated at full preheat volume. Furthermore, low gas velocity may cause backfires.

Manipulation of the torch, extremely important in flame washing, may be done in either of two patterns—(1) an oscillation with a forward motion or (2) a counterclockwise elliptical motion combined with a forward motion. Oscillation removes metal faster as more heat is reflected away with the elliptical motion.

The more common of the two patterns, and that used for straight washing of pads and more-or-less flat areas, is oscillation of the washing tip. If a pad is not larger than 3 or 4 in. in diameter, it is washed in one pass.

The torch is oscillated, with preheat flame only, over a small area (1 $^1/_2$ in. wide) to start a puddle and to bring the metal to kindling temperature. The tip is held at about a 30-deg angle to the surface and pointed in the direction of wash. When the puddle reaches kindling temperature, the washing oxygen is turned on and the forward oscillation motion continued across the pad.

The operator must judge the speed of torch movement from the condition of the surface. A fast motion produces a smoother finished surface with less danger of gouging and gives better control of the washing action.

No attempt should be made to wash any surface either too high or too thick. Experience teaches the operator what he can flame-wash successfully. Usually, any pad surface over $^1/_2$ in. in height is too high to remove by washing torch.

Pads larger than 3 or 4 in. in diameter require more than one pass. For a pad 8 to 12 in. in diameter, three or four parallel passes should be made. Overlapping of passes blends in and produces a uniform surface.

For single- or multiple-pass work, the casting should be positioned so that the wash angle is slightly downward. This allows the slag to run ahead of the wash and preheat the area to be cleaned. Flame washing should not be done in a vertical position as the slag runs off too quickly to provide any preheating effect.

The elliptical pattern is preferred for washing contour surfaces. It gives a flame concentration and action that quickly feathers the surface metal out into a smooth surface. As in washing by oscillation of the tip, an area is preheated to a puddle and kindling temperature before the washing oxygen is turned on.

While some operators may turn the oxygen on only during the retractory cycle of the elliptical motion, it is more common practice to keep it on continuously once the proper temperature has been reached. Manipulation of torch is simpler with continuous oxygen application and washing action is faster.

With either oscillation or elliptical motion, the operator should watch a small area ahead of the preheat flame and also that area directly beneath the end of the tip. Doing so permits him to feather excess metal down and to blend it evenly into finished dimensions and contours. The result is a smoothly finished surface free of bumps.

As an operator becomes highly experienced in use of the washing torch, he will likely—and naturally—vary from the techniques here recommended. In flame washing, as in welding, "feel" may mean the difference between a passable job and a very good one. For example, he may change torch position from the recommended 30 deg to the work surface to as low as 5 deg to get a more positive forward washing action. And he may vary gas pressures to suit work conditions and to get the best surface quality at minimum washing times. A good operator can wash off metal up to $^1/_2$ in. above the surface of the casting and blend it into the surface smoothly and rapidly.

Powder Washing

Stainless steels and other high-alloy steels (with more than 5% of chromium, nickel, molybdenum, etc.) are virtually impossible to wash with the conventional flame-washing torch. As soon as the flame hits the metal, refractory oxides of the alloying materials form on the surface and prevent further oxidation of the metal. With cast iron also, similar refractories stop the washing action.

So a special washing torch (Fig. 5) is used that adds a highly refined ferrous powder into the washing-oxygen stream of the torch. The powder fluxes and removes the refractory oxides, making it possible

and easy to flame-wash the metal surface. The intense heat, generated by the reaction between the powder and oxygen, melts the oxides as fast as they form, and the molten iron oxide from the reaction fluxes and dilutes the refractory oxides to form a fluid slag.

Washing action of the powder torch is not true oxidation, as in flame washing of mild steel with the conventional washing torch. Instead, the intense heat of the powder-oxygen reaction actually melts the material. A similar action—melting of the sand particles—permits a continuous washing action and makes the powder torch more efficient and faster than the conventional torch in washing off sand inclusions, sand penetrations and burned-on core sand.

The ferrous powder is fed to the torch from a powder dispenser consisting of hopper, ejector and a cylinder of carrier gas such as nitrogen or compressed air. The carrier gas, passing through the ejector, entrains, or picks up, the powder and carries it to the tip of the washing torch. A valve automatically controls powder flow.

Washing technique with a powder torch is practically the same as that with a conventional washing torch except that no preheating time is necessary. The burning powder gives an immediate and continuous kindling temperature so that washing can begin at once. As in conventional flame washing, the torch is manipulated with either the oscillation or elliptical motion, depending on work contour.

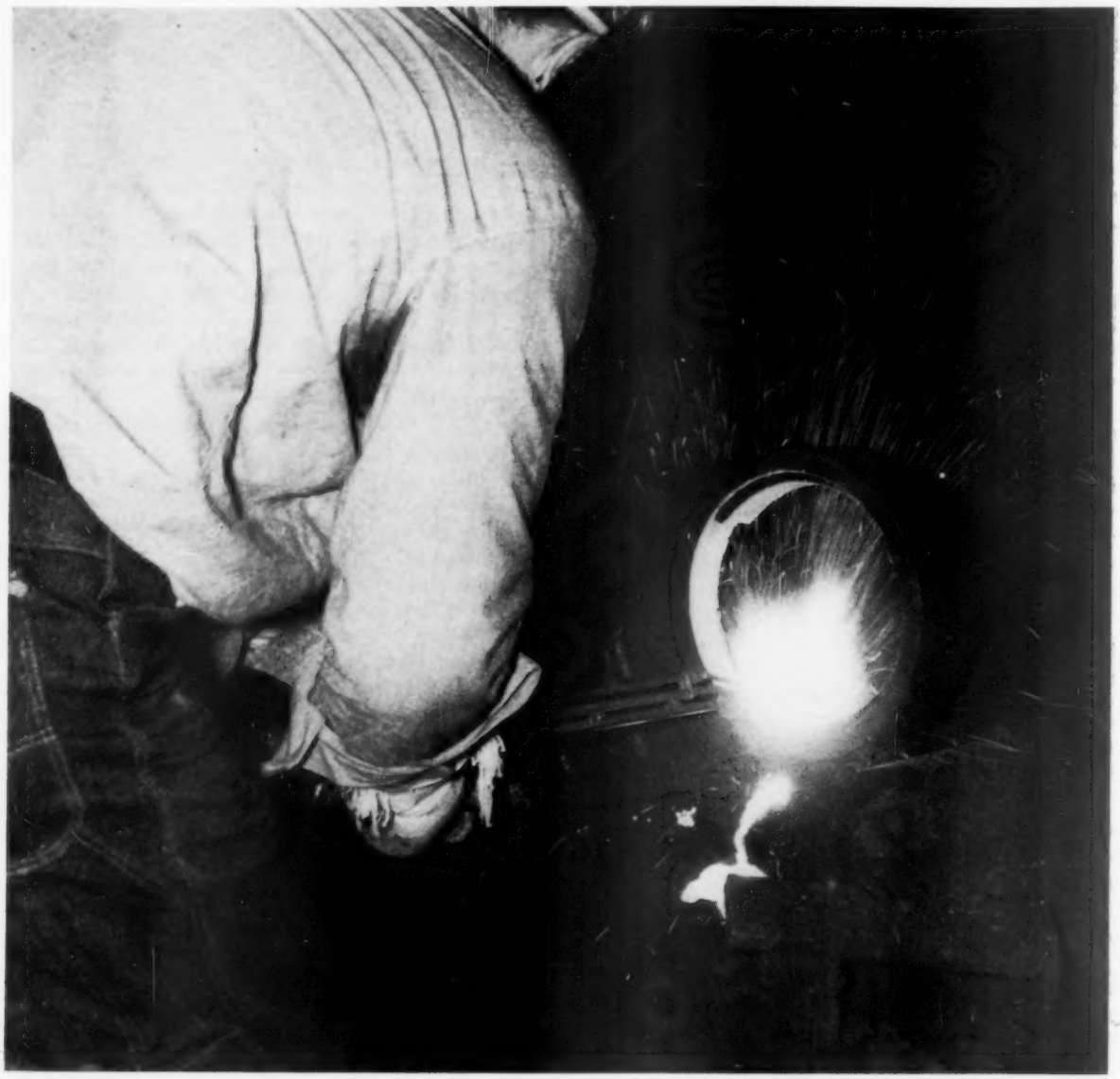


Fig. 5 Riser pads on stainless-steel casting are being removed with a torch using a ferrous powder fed into the washing-oxygen stream to provide an intense flame

Case hardening with distributed-jet "rocket"

ROCKETS FOR STEEL HARDENING

Extremely fast heating rates realized with rockets, followed by a water quench, found to produce hardness values higher than those obtained by more conventional heating techniques

BY JAMES A. BROWNING

ABSTRACT. Small rockets fueled by oxygen and propane have been investigated for the flame hardening of steel. The high-velocity, high-temperature jet of the rocket produces heat transfer rates nearly four times greater than those of open oxyacetylene flames. Progressive linear hardening at 35 ipm of flat specimens of 4150 steel produces maximum hardness of Rockwell C 68 with a case depth of $^{3}/_{64}$ in. Round shafts have been fully hardened at speeds up to 25 ipm. The extremely fast heating rates followed by a water quench produce hardness values higher than those obtained by more conventional heating techniques.

James A. Browning is associated with Thayer School of Engineering, Dartmouth College, Hanover, N. H.

To be presented at the 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

The Linear Rocket Hardener

The high heat transfer rates of a rocket jet make it necessary to distribute the flame evenly over the surface to be hardened. A row of small rocket orifices spaced approximately $^{1}/_{16}$ in. apart is not suitable for hardening. As this distributed-jet rocket progresses across the metal surface, alternate rows of hard and soft structure are produced.

A slot-orifice rocket has been developed which gives the required flame uniformity and makes the rocket hardening of steel possible. Propane and oxygen are metered into the unit at pressures of 80 and 100 psig respectively. Slots over one inch long by 0.040 in. wide have proved successful, although the tests discussed here have been limited to the slot size of

Fig. 1 Slot-rocket jet; slot dimensions—⅜ x 0.040-in.

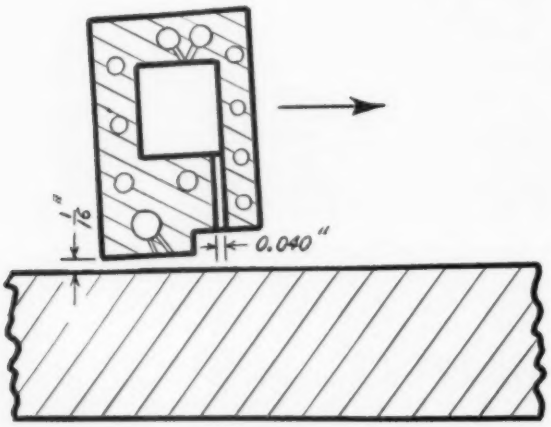


Fig. 2 Rocket in operating position

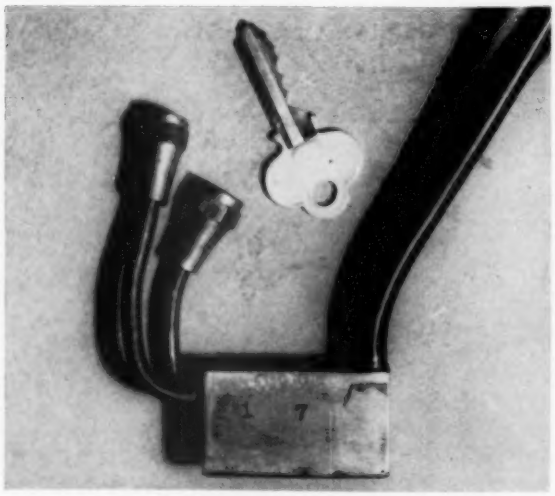


Fig. 3 Typical linear rocket hardener

⅜ by 0.040 in. Figure 1 is a photograph of the jet produced by this rocket. The alternate light and dark bands are due to the sonic, or higher, velocity of the jet. The jet temperature is approximately 5400° F and its velocity about 4000 fps. These figures represent a tenfold increase over the stream velocity of the oxyacetylene open flame. Convective heat transfer is greatly increased, and more than compensates for the lower values of radiant heat transfer. A relative comparison between the effectiveness of the two heat sources is given by the time required to begin melting the surface of a thick piece of steel. An oxyacetylene open flame takes longer than three seconds, while the propane-oxygen rocket requires less than one second.

Higher jet velocities may be obtained by providing an expanding nozzle beyond the minimum throat section of the rocket. The operation of such a supersonic nozzle is critical with regard to flow conditions. Also, the stream would exhaust at lower temperature over a wider area. As rocket thrust is not of primary interest in an application such as metal hardening, high thrust coefficients have been sacrificed in favor of simplicity. In fact, the irreversible processes associated with an underexpanding jet may well increase the effectiveness of the system to produce higher heat-transfer rates. The shock regions which exhibit high temperature and turbulence levels are augmented by this unbalance of exhaust and atmospheric pressure.

Conventional techniques of providing quench water to the heated zone prove most unsatisfactory. The rocket is most effective when the jet strikes the metal surface at nearly vertical incidence. Even with a tilt as large as 30 deg from the vertical a large backflow of these gases still exists. This flow is so intense that high-pressure water jets cannot penetrate to the metal surface. The jets are broken into a fine spray which is projected to the rear. By providing a re-

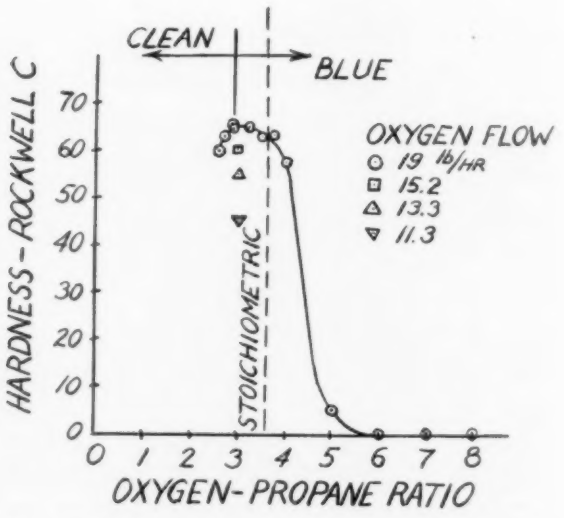


Fig. 4 Hardness as a function of oxygen-fuel ratio at a constant oxygen flow of 19 lb/hr

stricted flow path this reverse flow of gas can be eliminated. The $^1/_{16}$-in. clearance shown in Fig. 2 is occupied by quench water which is now allowed to perform its usual function.

Propane and oxygen pass from the drilled manifolds through a double row of inlet orifices to the combustion chamber. It is the location, size and number of these injectors which assures uniform jet distribution. Coolant passages are provided through which water circulates. The larger hole at the bottom of the rocket provides the quench water to the two rows of inclined holes.

Uniform movement of the rocket over the metal surface is provided by a machine cutting-torch carriage restrained to linear travel. Speeds between 2 and 60 ipm are available. Oxygen is provided from conventional high-pressure tanks, while the propane is supplied from a 100-lb cooking gas cylinder. Both gases pass through rotameters for flow measurement. The over-all dimensions of such a unit are qualitatively illustrated in Fig. 3.

Lighting the rocket is simple. The gas flow rates are adjusted to a low value. A conventional spark lighter is used to cause flame flashback into the combustion chamber. The flows may then be increased to their proper values. The quench water and carriage feed are then turned on. In most cases "flying starts" are possible, eliminating the usual preheat period.

Effect of Oxygen-Propane Ratio

The rocket produces a narrow band of bright red steel on the surface of the metal being hardened. This band is continuous across the length of the rocket slot and measures approximately $^1/_4$ in. in width by $^1/_{16}$ in. in depth into the metal depending on combustion intensity and speed of carriage feed. The steel contained in this above-transformation temperature region is quenched rapidly as the rocket moves forward. The relatively cold steel lying below acts as a heat sink, while the water quench causes a high cooling rate at the top surface.

The first series of runs were taken at a constant oxygen flow rate of 19 lb per hour at a feed of 27.7 ipm. The propane flow varied to give oxygen-propane ratios ranging from 8:1 to under 3:1. Due to the poor combustion characteristics of very lean mixtures, little hardening effect is experienced until the oxygen-propane ratio drops to values below 4:1 (see Fig. 4). Before hardening, the 4150 steel tested to Rockwell B75. Optimum conditions lie on the rich side of stoichiometric. Hardness readings shown in Fig. 4 are averages taken across the width of the hardened band. In various regions of this band, readings as high as Rockwell C68 were obtained. The hardness begins to fall as the mixture becomes too rich.

The curve of hardness as a function of the oxygen-fuel ratio closely follows the expected variation of flame velocity under the same conditions. Maximum flame velocities are reached at mixtures slightly richer than stoichiometric. Flame velocity is a measure of specific combustion intensity which may be defined as the rate of heat production per unit volume of reactants. High values of heat production give correspondingly high heat-transfer rates, all other conditions held constant. An excess of oxygen quenches the reaction causing lower specific heat release. Too great an excess of fuel reduces the kinetic reaction rate. Thus, an optimum oxygen-fuel ratio is to be expected. This ratio is slightly less than stoichiometric as an insufficient amount of time is available for the theoretically correct amount of oxygen to react with the fuel.

Figure 5 is a photograph of a vertical section through a hardened piece of 4150 steel. The surface has been polished and etched with a Nital solution. The maximum case thickness is $^3/_{64}$ in. Figure 6 is a photo-

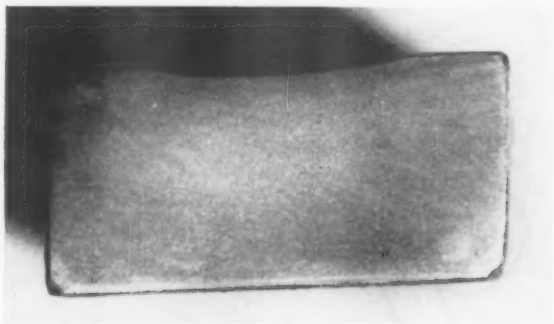


Fig. 5 View of etched cross section of hardened piece of 4150 steel

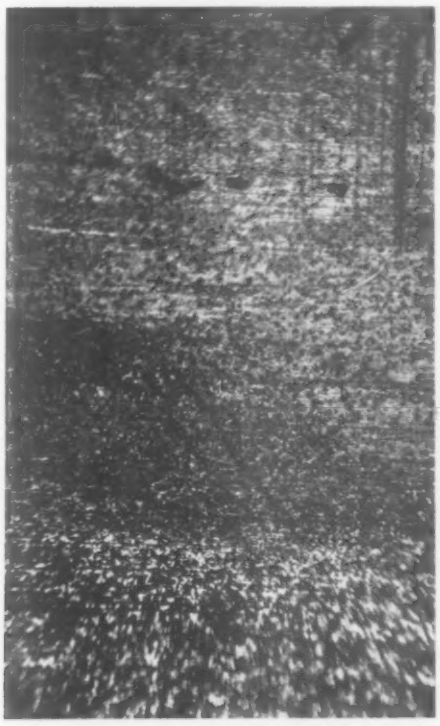


Fig. 6 Photomicrograph of hardened zone showing the three regions—fully hardened martensite, transition and unhardened

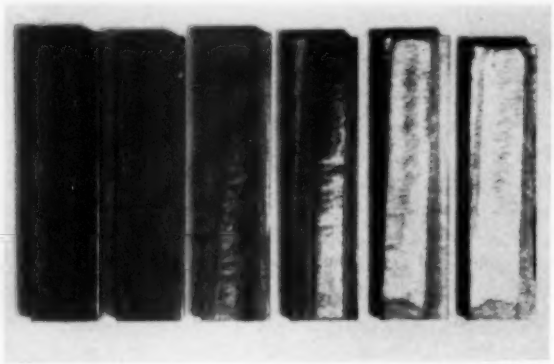


Fig. 7 Top view of sample specimens to illustrate change of surface color with oxygen-fuel ratio. From left to right, oxygen-fuel ratio: 8:1, 6:1, 4:1, 3.7:1, 2.88:1 and 2.72:1

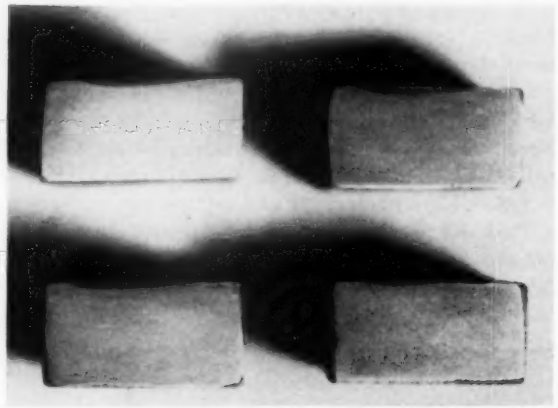


Fig. 8 Views showing variation of case thickness as a function of gas consumption. Constant O_2/f. Upper left O_2—19 lb/hr; upper right—15.2; lower left—13.3; lower right—11.3. Case depth a maximum of $^3/_{64}$ in.

micrograph taken at 100-power of a thin portion of the end view of this case. At the top of the picture can be seen the edge of the metal. The fully hardened martensitic region extends to a depth of 0.015-in., while the transition region is 0.017 in.

As the oxygen-fuel ratio is reduced to the value giving maximum specific heat release rates a change in surface color becomes evident. For mixtures containing excess oxygen a heavy "bluing" occurs. Lack of oxygen in the more suitable flames obviates the formation of such an oxide film. The result is an exceptionally clean finish. Figure 7 shows the variation of surface color as a function of the oxygen-fuel ratio. The presence of the quench water immediately behind the flame jet excludes the atmosphere from the hot surface, thus eliminating the only other source of oxygen. Runs made using optimum rocket conditions, but with no water quench, produced the blue oxide coating. The combination of proper oxygen-fuel content in the jet and the geometric relationship between this jet and the water quench is critical in producing this fine finish.

Effect of Oxygen Flow Rate at Optimum Oxygen-Fuel Ratio

As the flow is reduced at constant oxygen-fuel ratio less combustion takes place in approximately the same volumetric space. The combustion pressure falls and the rocket jet becomes less effective in producing high specific heat release rates. The red-hot band which travels across the metal surface becomes reduced in size.

Figure 4 shows three additional points taken at the constant feed of 27.7 ipm and oxygen-fuel ratio of 3:1. The oxygen consumption is the variable. The surface hardness is apparently lowered by this reduction in flow. However, Rockwell A tests indicate that these surfaces are equally as hard as those for the larger oxygen flows. Figure 8 illustrates the reduction in depth of case for these points. The Rockwell C scale does not give accurate readings for such thin cases.

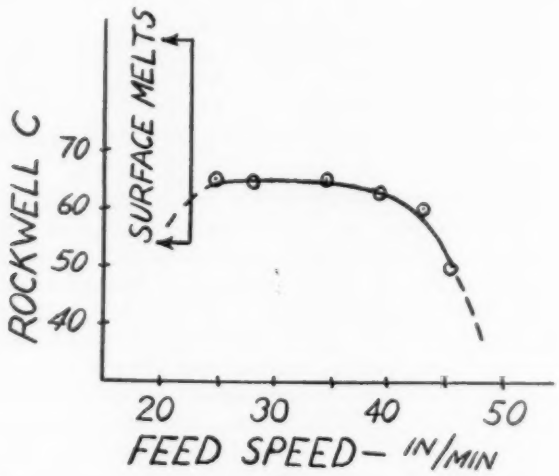


Fig. 9. Hardness as a function of carriage speed. O_2/f—2.88:1. Oxygen consumption 19 lb/hr

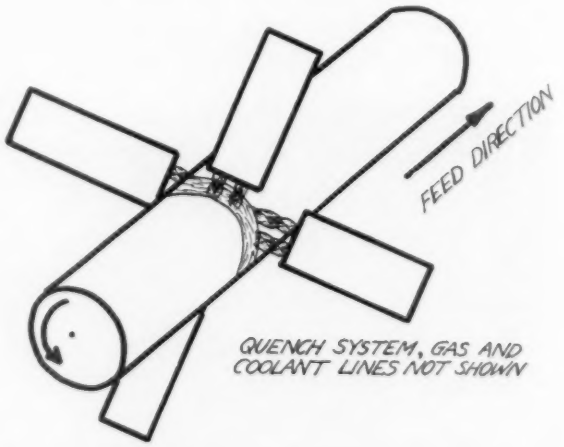


Fig. 10 Rotary hardening setup

Effect of Carriage Speed on Hardening with the Oxygen-Fuel Ratio and Gas Consumption Constant

Figure 9 illustrates the effect of carriage speed on hardness produced. Until a speed of nearly 25 ipm is reached the surface layers are melted and blown away. Maximum Rockwell C readings are obtained up to a speed of about 38 ipm with an apparent drop-off at higher speeds. Rockwell A readings again indicate that the surface is fully hardened out to 45 ipm.

It appears that so long as the surface layers of the metal are raised above the transformation temperature that maximum hardness will be reached using a water quench. The depth of hardness is easily controlled either by a variation in oxygen consumption or by a change in the feed rate. Visually, the surface must be heated to a bright red color. The rocket jet is quite pale in intensity and does not mask visual observation of the region being heated.

Rotary Rocket Hardening

The chief problem in linear hardening is developing a rocket unit to give nearly uniform jet distribution across the entire length of the exhaust slot. This problem is eliminated in rotary hardening due to the rotation of the piece being hardened. Several rockets may be used at the same time. At any given instant there is an uneven distribution of heat around the shaft. However, the rotation of the piece gives every area of the surface an opportunity to be heated equally. Figure 10 is a diagrammatic sketch of this setup. Four separate, two-throat rockets, spaced 90 deg apart around the circumference of the shaft, have been found to be adequate to surface harden fully a $1^1/_2$-in. diam shaft at a longitudinal feed velocity of 25 ipm.

Figure 11, a cross-sectional view of a rocket-hardened shaft, shows a uniform depth of case of $^1/_{16}$ in. This case depth is remarkably uniform in longitudinal direction as well.

Hardness values higher than those associated with conventional heat treating devices are obtained for rotary rocket hardening as well as for the linear case. A small portion of the surface at the end of the shaft was hardened to Rockwell C70. This area represented the location where the rockets were turned off. The quench progressed across the red-hot band experiencing no interference from a backflow of gases from the combustion zone. By use of a more effective quench over the whole shaft, it might well be possible to harden the entire surface to comparable high hardness.

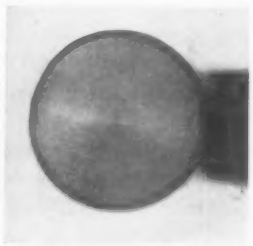


Fig. 11 Rotary hardened shaft, $1^1/_2$ in. in diam

It is believed that the high hardness values obtained by rocket use is due to the rapid heating cycle. In many cases it has been reported that the more intense heating effect of high-frequency induction equipment produces case hardnesses several Rockwell numbers higher than those produced by slower open-flame hardening. Rapid heat input allows the material to remain above the transformation temperature a short period of time with the result that little grain growth is experienced. Also, more rapid heat input produces thinner case sections allowing a more effective quench by the cooler metal beneath.

The entire heating and cooling cycle above a reference temperature of 300° F can be made to be less than two seconds by use of rocket hardening. This is faster than induction hardening which requires several coils for rapid longitudinal travel.

Cost Comparison of Rocket and Oxyacetylene Open-Flame Hardening

Assuming a cost of $0.01 per cubic foot of oxygen and $4.50 per 100-lb cylinder of propane, the data collected for the optimum rocket runs show a cost of $0.0025 per square inch of surface hardened. Some 1050 in.^{2} of surface are hardened per hour using a $^5/_8$-in. wide slot. For a case depth of $^3/_{64}$ in., the cost per cubic inch of hardened material is $0.053.

The costs for oxyacetylene have been calculated using data obtained from the *Metals Handbook*, 1948 edition. Assuming a depth of hardening of $^1/_8$ in. and a cost of acetylene of $0.025 per cubic foot, the cost of $0.0049 per square inch is obtained. On a volume basis the cost is $0.038 per cubic inch, which is slightly less than that for the rocket.

In many cases a deep depth of hardening may not be required. On a cost per unit area of surface, the rocket is about half that of the open flame. In fact, thin cases require a minimum of heat input, and distortion of the piece is held to a low value.

Labor costs may be a controlling factor. The many times higher feed rates associated with rocket hardening should produce substantial labor savings. Also, the high investment of an automatically controlled machine will be spread over many more pieces.

Closure

These rather preliminary tests using rocket jets for flame hardening are sufficient to show the practical fields of their application. Small rockets will produce maximum hardness depths of nearly $^1/_{16}$ in. This is well below the range produced by open oxyacetylene flames. Thus, a new field is open for flame hardening.

Further development work is required. Also, a more fundamental program to investigate the mechanism by which high heat input rates produce high hardness values should be undertaken.

Acknowledgment

This program has been sponsored by the Cincinnati Milling Machine Co., Cincinnati, Ohio, and the author wishes to thank them for their cooperation.

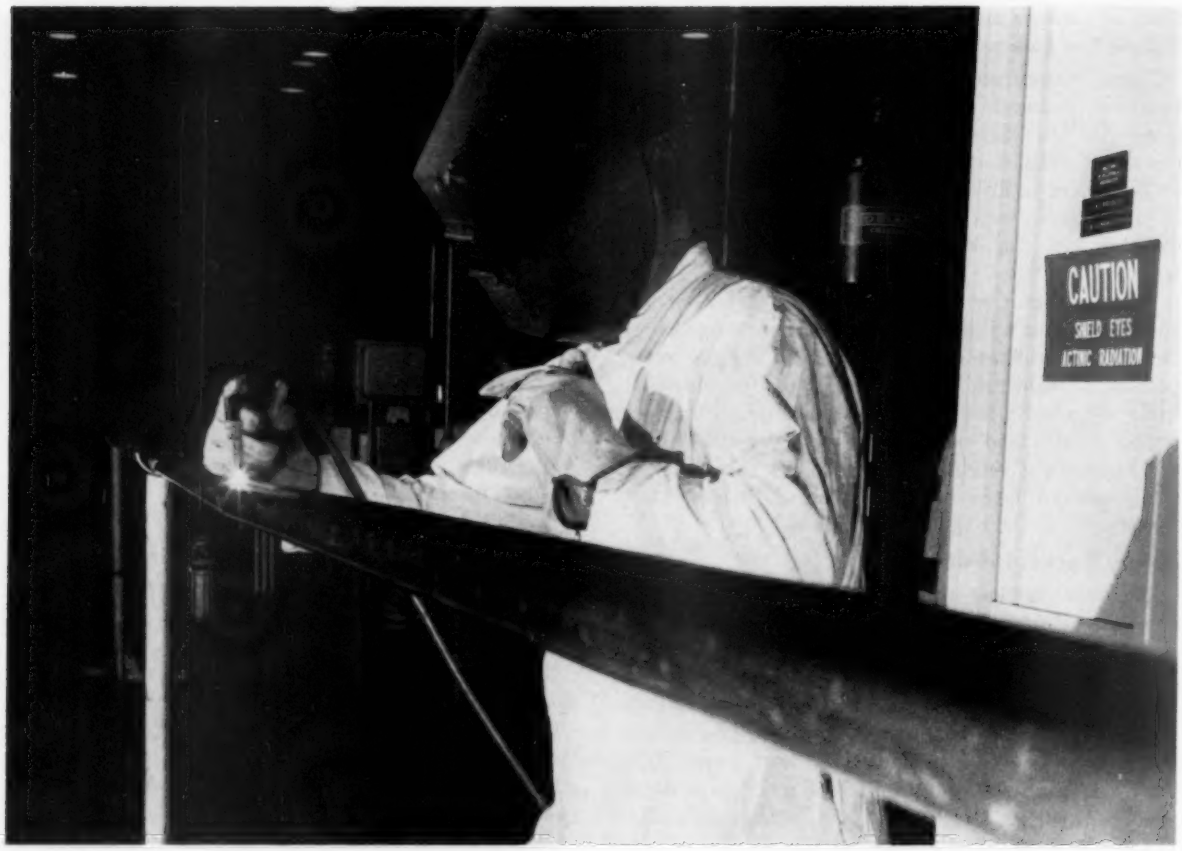


Fig. 1 Inert-gas tungsten-arc butt welding 50-ft Zircaloy tube

INERT-GAS TUNGSTEN-ARC BUTT WELDING OF ZIRCALOY-2 TUBES

Techniques for welding internally ribbed Zircaloy tubes are described and mechanical, metallurgical and corrosion data are presented

BY J. W. LINGAFELTER

Introduction

The fabrication of $1^{3}/_{4}$-in. diam by 0.045-in. wall internally ribbed Zircaloy-2 tubes in lengths greater than 30 ft has so far met with limited success.[1] Where tubes greater than 30 ft long are required, one approach that is commercially suitable for producing longer lengths involves the joining together of two or more tubes by inert-gas tungsten-arc butt-welding techniques. This paper describes the techniques employed for inert-gas tungsten-arc welding internally ribbed Zircaloy tubes and presents mechanical, metallurgical and corrosion data obtained on duplicate test samples to determine weld properties.

J. W. Lingafelter is associated with Hanford Atomic Products Operation, General Electric Co., Richland, Wash.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Work performed under Contract No. W-31-109-Eng-52 between the Atomic Energy Comm. and General Electric Co.

Summary

A 52-ft length of internally ribbed Zircaloy-2 tube was produced by inert-gas tungsten-arc welding together three shorter length pieces. Radiographic inspection of the welds showed that the welded joints were fully penetrated and contained no significant porosity, voids or contaminants. Mechanical, metal-

lurgical and corrosion testing of duplicate test samples indicated that strong, ductile and corrosion-resistant welds can be produced by the procedure described. In addition, the ease with which tubes may be joined by inert-gas tungsten-arc welding has been demonstrated.

Tube Butt-Welding Operation

Description of Equipment and Material

Equipment. The welding was done with a hand torch and a 250-amp dc-rectifier welder power supply (equipped with a remote control foot switch). A copper backing plug, Fig. 2, was used to provide inert-gas shielding to the weld underside, to control weld penetration and to insure alignment between the abutting tube pieces.

Material. Zircaloy-2* tubes with internal ribs parallel to the tube axis were available at Hanford in lengths ranging from 31 to 4 ft. The tubes had been tube reduced from extruded ribbed blanks to approximately $1^{3}/_{4}$-in. diam by 0.045 in. wall thickness.

Description of Welding Procedure

Joint Design. Because the ribs represented a region of increased heat-absorbing capacity, a joint design was required that would insure full weld penetration at the ribs during the welding pass. Figure 2 illustrates the joint design adopted, which was prepared by machining the tube ends square followed by milling out the rib and tube wall as shown.

Backing Plug. The abutting process tube lengths were kept in alignment by using a snug fitting copper backing plug (Fig. 2) that had two grooves matching the tube ribs. The backing plug had a diameter 0.020 in. less than the inside diameter of the tube, which insured good tube alignment and prevented excessive weld penetration during welding.

An additional function of the copper backing plug was to provide inert-gas shielding to the tube interior. The plug was made with a $^{1}/_{4}$-in. center axial hole and $32\,^{1}/_{16}$-in. radial holes that extended from the plug outer surface to the $^{1}/_{4}$-in. axial hole. Inert gas was introduced to the backing plug through a $^{1}/_{4}$-in. pipe that extended the length of the tube.

Tube Butt-Welding Procedure

Three tube lengths, 30, 14 and 8 ft long, were selected for welding together into a 52-ft length. Before welding the 52-ft length together, qualifying welds were made on four 8-in. length test sections. These test sections were used to determine the properties of the welded tube as reported later. Prior to welding, the tubes were degreased and the tube ends wire brushed. The copper backing plug was then positioned in the tube such that the $^{1}/_{16}$-in. radial holes were in line with the tube ends. Helium, which was used for the tube purging gas, was connected to the $^{1}/_{4}$-in. pipe attached to the backing plug. The flow of helium (10 cfm) was started 10 min before welding and was continued for 5 min after welding.

The tubes were manually welded together in the flat position (Fig. 1); straight-polarity welding current and argon shielding gas were used. The abutting tube ends were initially tack welded together in three places to prevent misalignment during welding by warping or handling. The grooved rib areas were welded next by first fusing the bottom of the rib and then adding Zircaloy filler metal to fill up the grooved joint. After completion of the rib joints, the full tube circumference was welded. One tube joint was a simple one-pass fusion weld while the second was a two-pass weld with filler metal added during the second pass. Approximately 100 amp, with an attendant welding rate of about 10 ipm, was required to obtain full penetration. Argon was used for the torch shielding gas because experience had shown that the heat input could be controlled better and that less warpage was generally encountered than when helium was used.

No special precautions were taken during welding to protect the tube outer surface from atmospheric gas contamination. It was felt that this latitude could be taken because the outer surface of the tube would not normally be exposed to a corrosive environment

Welded Tube Testing

Longitudinal specimens were cut from welded and unwelded 8-in. test samples to evaluate mechanical, metallurgical and corrosion properties of as-received, annealed, welded and welded and annealed tubing. Radiographic inspection of the welds in the 52-ft tube was performed to determine weld penetration, porosity, voids and contaminants. The results of the testing are described herein.

Radiographic Examination

Results of radiographic examination of the two welds in the 52-ft length are shown in Figs. 3 and 4. The single-pass weld, Fig. 3, has complete penetration, a lack of voids and porosity and several isolated areas of insignificant tungsten particles. The two-pass weld,

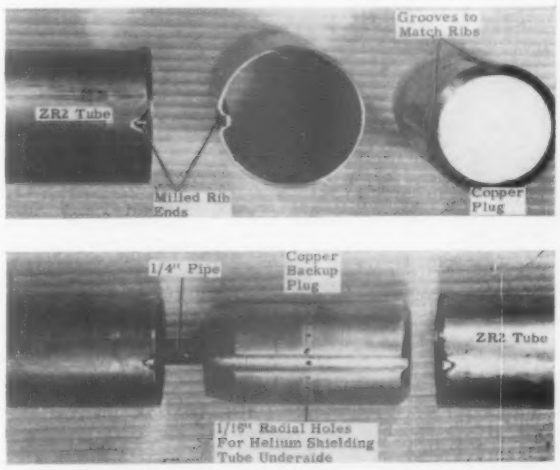


Fig. 2 Components for butt welding Zircaloy tube

* A zirconium alloy containing 1.5 w/o tin, 0.15 w/o Fe, 0.05 w/o Ni, 0.10 w/o Cr.

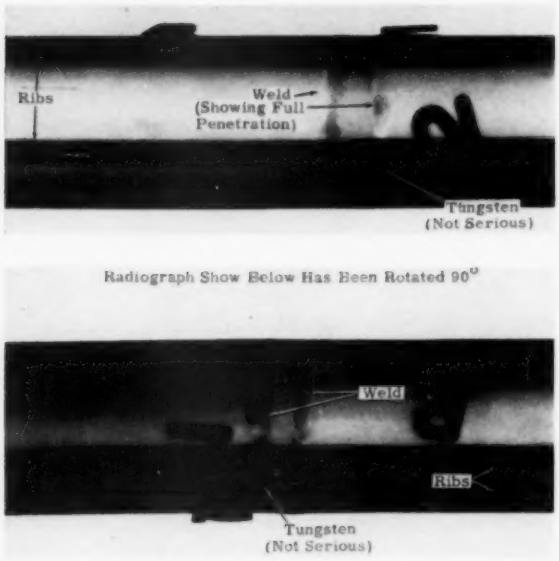


Fig. 3 Radiographs of single-pass weld in 50-ft tube

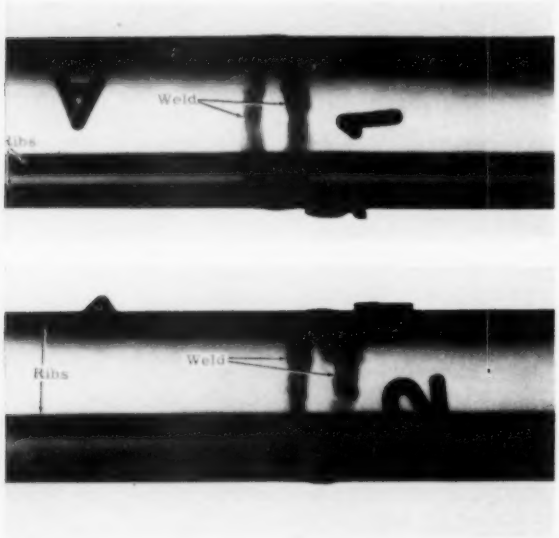


Fig. 4 Radiographs of double-pass weld in 50-ft tube (two views 90° apart)

Fig. 4, also has complete weld penetration and no voids or porosity.

Metallographic Examination

Longitudinal test specimens from Zircaloy tube samples in the as-received, annealed, welded and welded and annealed conditions were microscopically examined. The examination showed that the welds were free of defects (voids, porosity, cracks) and that the weld and heat-affected zones contained no unusual phase constituents.

Figure 5 shows photographs of the butt-welded joint. Note that the following structure zones are

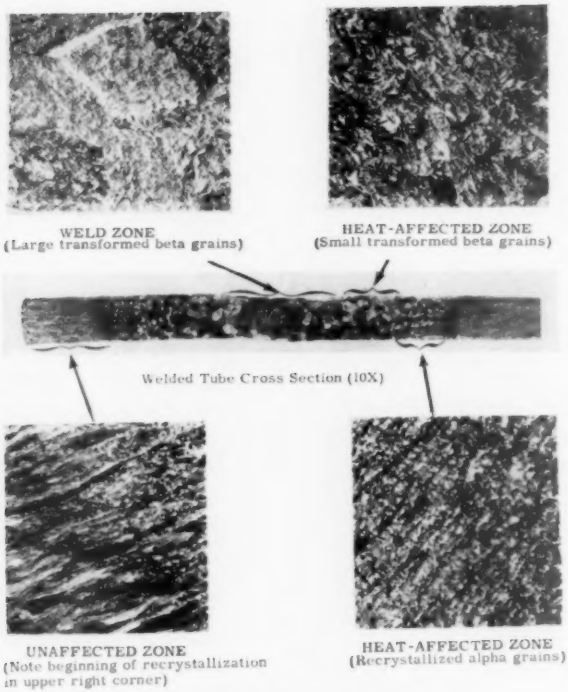


Fig. 5 Photographs of longitudinal section from welded Zircaloy-2 tube. X 100, polarized light. (Reduced by 50% upon reproduction)

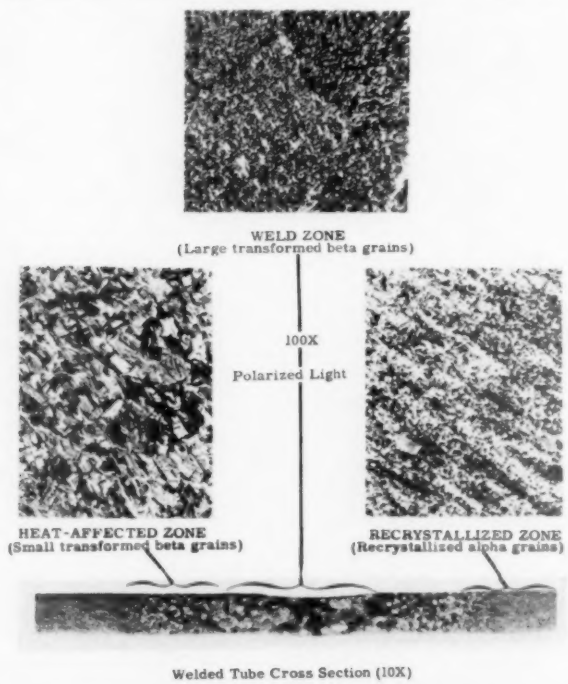


Fig. 6 Photographs of longitudinal section from welded and annealed Zircaloy-2 tube. (Reduced by 50% upon reproduction)

apparent: (1) weld zone, (2) heat-affected zone and (3) unaffected base material.

The weld zone contains large transformed beta

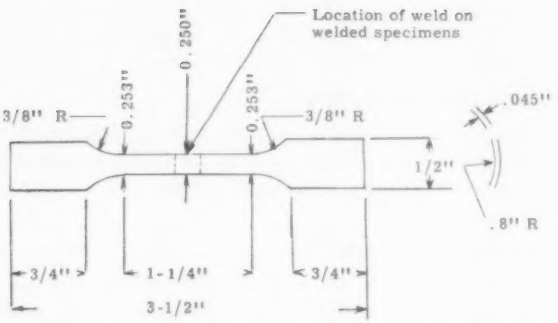


Fig. 7 Dimensions of tensile specimens used in Zircaloy welded-tube study

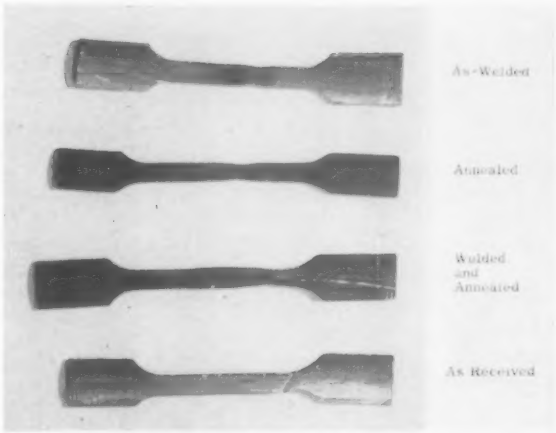


Fig. 8 Tensile tested Zircaloy tube samples

grains and represents actual melting of the Zircaloy. Adjacent to the weld zone is the heat-affected zone which contains two distinct parts. Immediately adjacent to the weld is a zone in which the temperature exceeded the transition temperature (865° C) but not the melting temperature (1845° C). This zone has smaller transformed beta grains than the weld. The second part of the heat-affected zone is the region where the temperature did not exceed the transition temperature, but was sufficiently high to cause recrystallization of the cold-worked base metal. It can be seen that complete recrystallization did not occur in this zone and that alpha grain growth was not appreciable. The unaffected base metal represents a region entirely excluded from the annealing effects of welding. The structure shown is typical of about 60% cold work.

As-received and welded tube samples were salt-bath annealed at 750° C for 2 min and water quenched to determine the effect of annealing on structure and mechanical properties.[2] Figure 6 contains a photograph of the annealed welded specimen. Although recrystallization of the cold-worked structure occurred, the annealing produced no structural changes in the weld zone or heat-affected zone.

Tensile Tests

Room temperature tensile tests were made on longitudinal specimens cut from as-received, annealed, welded and welded and annealed tube samples. The specimens were machined as shown in Fig. 7. The test results, Table 1, are in agreement with published data for Zircaloy-2 mechanical properties.[3] Note that the tensile and yield strengths of the as-welded tube, though naturally lower than the as-received tube, are considerably higher than the annealed tube

Table 1—Room-Temperature Tensile Test Results for Zircaloy Tubes in the As-Received, Annealed, Welded and Welded and Annealed Conditions

*Sample no.**	*Sample identification*	*Tensile strength, psi*	*0.2% yield strength, psi*	*Elongation 1 in., %*	*Fracture occurred in*
1*	As-welded tube	85,300	50,800	8.0	Heat-affected zone
1R*	As-welded tube	87,800	67,500	3.0	Heat-affected zone
4	As-welded tube	84,100	60,900	6.0	Heat-affected zone
4R	As-welded tube	85,600	63,300	4.0	Heat-affected zone
5	As-welded tube	84,500	63,700	8.0	Heat-affected zone
5R	As-welded tube	86,800	60,400	5.0	Heat-affected zone
6	As-received tube	108,600	92,100	†...	.....
6R	As-received tube	106,800	92,400	...	.....
7	As-received tube	104,600	87,800	...	.....
7R	As-received tube	111,500	103,400	6.0	.....
8	As-received tube	102,400	94,000	...	.....
8R	As-received tube	108,600	101,100	...	.....
9	Annealed tube	67,000	38,400	26.0	.....
9R	Annealed tube	74,700	43,000	19.0	.....
10	Welded and annealed tube	75,200	45,700	10.0	Heat-affected zone
10R	Welded and annealed tube	75,000	46,800	14.0	.....
Avg	As-welded tube	85,700	61,100	...	.....
Avg	As-received tube	107,100	96,300	...	.....
Avg	Annealed tube	70,800	40,700	...	.....
Avg	Welded and annealed tube	75,100	41,200	...	.....

* Two test specimens from each tube were tested: one between the ribs (*R*) and one opposite the ribs.
† Broke outside of gage length.

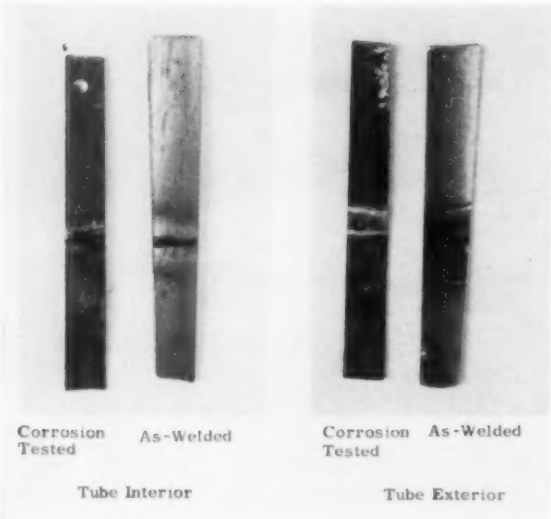


Fig. 9 Zircaloy welded-tube samples corrosion tested 6 months in 350° C deionized water

specimens. Note also, as indicated by samples 9, 9R, 10 and 10R, that the weld and heat-affected beta structure are stronger than the recrystallized alpha structure. The yield and tensile strengths of Zircaloy with a beta structure are generally reported to be about 20 and 10% higher, respectively, than Zircaloy with an alpha structure.[3] Typical fractured tensile specimens are illustrated in Fig. 8.

Corrosion Evaluation

Corrosion test specimens from as-received, as-welded, annealed and welded and annealed process tube samples were corrosion tested in 350° C deionized water for 6 months. Figure 9 illustrates several corrosion test specimens of welded tubes that were exposed for 6 months. Note the absence of any corrosion product on the weld, heat-affected zone and base metal on the tube interior, which indicates adequate helium shielding during and after welding. The tube exterior was only shielded with argon from the torch. This lesser degree of shielding appears to be responsible for some corrosion of the tube exterior. However, no extensive corrosion was observed (Fig. 10).

Gas Analysis

The results of chemical analysis on as-received and as-welded tubing are reported in Table 2. The helium shielding used to protect the tube underside during welding appears adequate from the concentrations of O_2, N_2 and H_2 in as-welded and as-received specimens. Even when no gas backing is employed, the values of O_2, N_2 and H_2 concentrations are not excessive.

Table 2—Gas Analysis Results for Zircaloy As-Received and As-Welded Tubes

Sample identification	H_2, *ppm*	O_2, *ppm*	N_2, *ppm*
As-received tube	19	1210	55
As-welded with helium backing	19	1450	56
As-welded with no backing	51	1690	101

Discussion of Results

The following discussion of the test results indicates that butt-welded Zircaloy tubes should be acceptable for use where temperature and pressure environment are not excessive.

Corrosion Performance

Results of radiographic and metallographic examinations and gas analyses show that the welded joint has good corrosion resistance. Factors conducive to good corrosion performance of the welded joint are: (1) the lack of weld root cracks, which precludes crevice corrosion; (2) the absence of unusual phase constituents in the weld and heat-affected zones that might cause intergranular or galvanic corrosion; (3) the comparative O_2, H_2 and N_2 concentrations between as-received and as-welded specimens, which indicates that impaired corrosion resistance from gas pickup should not occur. The results of the 6-month corrosion test at 350° C, as shown in Figs. 9 and 10, support the above conclusions.

Mechanical Performance

The values of mechanical properties for welded tubes given in Table 1 are not particularly meaningful until they are compared with the properties of the nonwelded tubes, and discussed in the light of anticipated performance requirements. A Zircaloy tube should have sufficient strength to withstand internal stresses when subjected to the particular operating pressure it was designed for. One way to compare welded and nonwelded Zircaloy tubes is to determine their allowable service operating pressures.

The allowable internal operating pressure for a tube can be calculated from:

$$S_c = \frac{1.5PD}{2t}$$

where the tube is assumed to be free floating for stress considerations and the circumferential stress is the major stress.

S_c = allowable circumferential stress in the tube wall = yield strength of the tube (96,300 for nonwelded tubes and 61,100 for butt-welded tubes)
D = tube diameter (1.640 in.)
P = internal operating pressure
t = tube wall thickness (0.045 in.)
1.5 = safety factor

for nonwelded tubes

$$P = \frac{96{,}300 \times 2 \times 0.045 \times 2}{3 \times 1.640}$$
$$= 3520 \text{ psi}$$

for butt-welded tubes

$$P = \frac{61{,}100 \times 2 \times 0.045 \times 2}{3 \times 1.640}$$
$$= 2230 \text{ psi}$$

The above calculations show that butt-welded and nonwelded tubes could safely be used with an internal

pressure of about 2200 and 3500 psi, respectively. These values are for room temperature only because a decrease in yield strength will naturally occur as temperature increases. Although at room temperature a butt-welded tube could operate with an internal pressure only 63% of the nonwelded tube, there are few room or low-temperature applications for Zircaloy tubes. Economic justification for Zircaloy tubes normally is based on the reasonable strength and good corrosion resistance properties that are available at elevated temperatures (300–500° C). Recent work at the Hanford Atomic Products Operation has shown that the room temperature yield and ultimate strengths of cold-worked Zircaloy-2 is decreased significantly within a period of 2 weeks at 360° C.[4]

This apparent flow stress recovery of Zircaloy-2 was observed to decrease the room-temperature yield strength of 65% cold worked material 10% after 2 weeks at 360° C and 13% after 16 weeks at 360° C. A decrease of about 40% would be equivalent to an annealed condition.

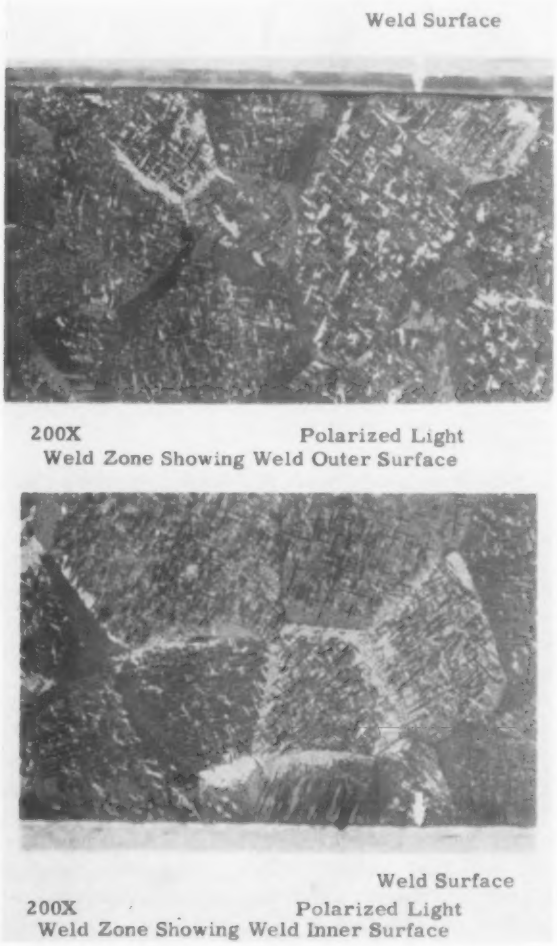


Fig. 10 Micrographs of Zircaloy tube butt weld corrosion tested 6 months in 350° C deionized water. (Note lack of corrosion product or corrosion attack.) (Reduced by 25% upon reproduction)

It appears that should appreciable recovery occur at elevated temperatures over long periods of time, butt-welded Zircaloy tubes would be as satisfactory as nonwelded tubes.

Zircaloy Tube Weldability

The experience gained in butt welding a number of Zircaloy tube ends together indicates that the material is readily weldable. Penetration can be accurately controlled, although full penetration is extremely difficult to obtain if tight backup is employed. It was for this reason that the copper backing plug had a diameter 0.020 in. less than the tube ID. Porosity, blowholes or voids in the welds were not encountered to any significant degree. There were indications during the early development work that weld porosity was related to the cleanliness and surface condition of the material. Degreasing and wire brushing were found to be sufficient for the tube welding operation to insure porosity-free welds. The use of a filler pass on one of the two welds in the 52-ft length did not materially add to the welded tube properties.

Experience did show that Zircaloy filler can be added to the puddle in a routine manner. Should a filler pass be required, the material could be automatically introduced into the puddle using a continuous length of wire.

The butt-welding procedure described in this report for joining together two or more lengths of Zircaloy tubes should be adaptable to an automatic welding operation. Standard commercially available equipment would be directly usable for the tube butt-welding operation. Such equipment would include: a rotating fixture to hold the tubes in good axial alignment (i.e., glass working lathe), an automatic welding head that maintains constant arc length, an automatic filler-wire feeder unit (optional) and the standard supply of air, water and inert gases. Should better protection of the tube outer surface during welding be required, a trailing shield attached to the torch gas nozzle would normally be sufficient.

Conclusions

From the information presented, it can be concluded that internally ribbed Zircaloy tubes can be successfully inert-gas tungsten-arc butt-welded together to form long lengths of tubing. The welding procedure described is readily adaptable to an automatic operation using standard commercially available inert-arc welding equipment.

X-ray quality welds with good mechanical, metallurgical and corrosion properties can be made using the inert-gas tungsten-arc welding procedure described. Butt-welded tubes can be expected to have good corrosion performance at 350° C and adequate room temperature mechanical properties for use with internal tube pressures of 2200 psi or less.

References

1. Johnson, D. E., HW-36763, May 19, 1955.
2. Johnson, D. E., *A Study of Short Time Annealing of Cold Worked Zirconium*, HW-41372, Feb. 29, 1956 (Unclassified).
3. Mudge and Forscher, WAPD-101, July 3, 1954 (Confidential).
4. Johnson, D. E., HW-40312, Dec. 7, 1955.

180-ft welded rigid frame

A SHORT COURSE IN WELDED RIGID FRAME DESIGN

Paper aims to provide practical answers to a number of important questions on welded rigid frame design

BY MARTIN P. KORN

Martin P. Korn is Consulting Engineer, Boca Raton, Fla.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Introduction

In lectures given at many universities on welded rigid frame design, questions most often asked were "How can we approximate sizes and shapes of members without having to recompute our results repeatedly through trial and error? What spacing of bents is most economical? How about radius of haunches, types of bases—hinged and fixed, slope of roof, bracing, sway frames, etc., for economic and practical design?"

Specific questions of that type came more frequently from professors of engineering than from students. And the reason therefor is plain; the particular answers they wanted pertaining to design were carefully bypassed in textbooks. They are based on experience. So they were not taught in colleges. Similar questions were asked at lectures before professional societies around the country, and some consultants asked also for short computation methods or tables. They considered fees received insufficient to justify lengthy calculation costs by standard procedures such as moment distribution, slope deflection, least work and others.

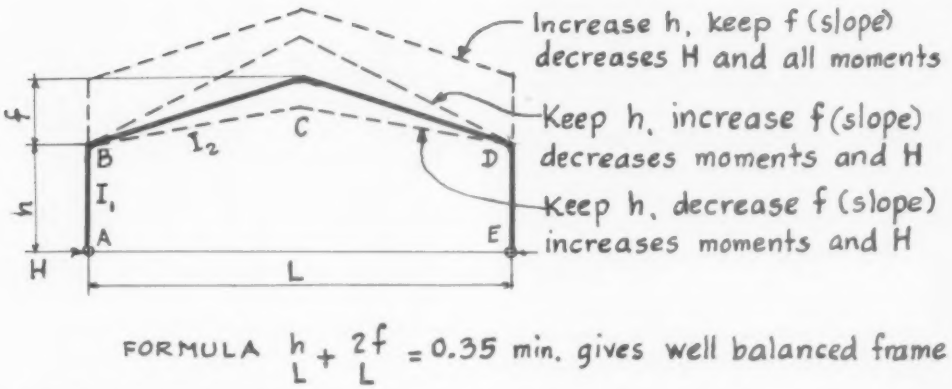


Fig. 1 Formula for balanced design and economy

Analysis of Problem

This paper aims to provide practical answers to the above questions and to others; it combines data never published before, based on forty-five years of experience and research, and makes possible the quickest design in the shortest possible time. It was taken from a three-day "Short Course on Welded Rigid Frame Design" recently given by the author at the University of Miami, Evening Division, to 106 professional engineers and architects. Prerequisite for admission was a knowledge of the theory of indeterminate structures.

For an illustrative example, a welded rigid frame building-span 180 ft (see lead photo), designed by the author, was analyzed. The University of Miami elected to compute the principal moments and horizontal thrust by moment distribution. The time consumed was 14 hours. The author used a contracted method based on the classical theory of least work; time consumed was 12 minutes on a calculating machine. Results were compared and found almost 100% identical, which means 100% correct theoretically. Variations were in mere fractions of one percent. Since moment distribution is standard procedure known to all engineers, the University's solution is omitted to save space. Given here for the first time in print is what will be called the *12-Minute Method* (see Fig. 7) for lack of another name. (Undergraduates employed by author averaged less than 12 min per rigid frame.)

Following the above analysis, slides were shown of fourteen case studies of actual rigid frame structures with critiques by the author emphasizing the *do's* and *don'ts* for safe, economic and practical design. Case A revealed uneconomical sections with heavy cover plates for rafters and columns. Case B, very expensive pins for hinged bases where inexpensive flat plates could have been used. Case C, a radius too shallow for the inner curved flange of knee making for higher stresses in that area. Case D, too flat a roof on a large span which involved more steel and higher costs. Case E, a 136-ft span rigid frame building where

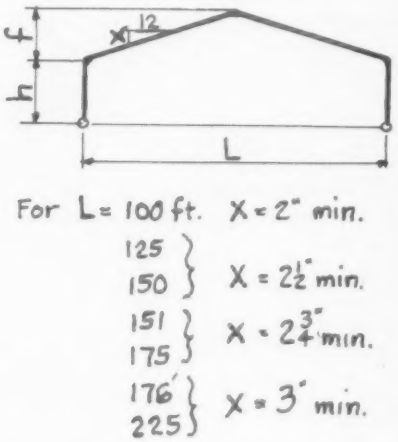


Fig. 2 Minimum roof slopes

ties between column bases were pretensioned with only one support at center. Other cases which indicated similar faults and weaknesses in design.

The general data which follows in compacted form serves to avoid the above faults and answers most questions for good design visually by means of sketches and tables that are self-explanatory, simple and instantaneous. For your first step, refer to Fig. 1 with dimensions L, h and f which are usually given to you and see that they satisfy the formula given for balanced design and economy. If results are under 0.35, a slight change in h or f or both may give the desired results. Figure 2 showing minimum roof slopes for economy will help guide your change. A balanced design as considered here is one without excessive stress in the ties or knees for any given span. If, for example, dimension h is short, say 10 ft, and the span long for that low height, say 100 ft, the stress in the ties and in the knees will be excessive for economy. A slight increase in h with perhaps a slight increase in roof pitch from Fig. 2 will decrease the excess stress in the tie and knees.

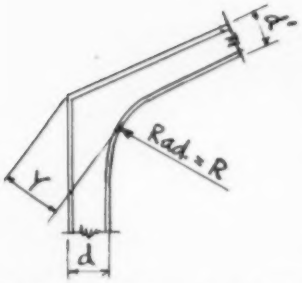
16, 18, 20 ft	for spans 50 to 100 ft
1/5 to 1/6 L	for spans 101 to 150 ft
1/5 to 1/7 L	for spans 151 to 200 ft
1/6 to 1/8 L	for spans over 200 ft

L = span (distance c. c. cols.)

Fig. 3 Bent spacing

Span, ft	Rafter, in
60	14 to 16
75	18 to 21
100	21 to 24
125	27 to 33
150	36 to 42
175	42 to 48
200	48 to 54
225	60 to 72

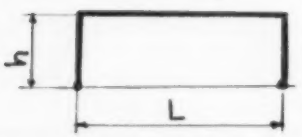
Fig. 4 Size of rafters



R = 2 1/2 to 3 1/2 smallest of d or d'

V = 2 to 2 1/2 smallest of d or d'

Fig. 5 Round-knee dimensions



For spans under 90 ft, h = L/6 min

For spans over 90 ft, h = L/5 min

Fig. 6 Square-knee frame

Through Figs. 1 and 2, you have now determined an economic skeleton for your frame. Next, select your bent spacing from Fig. 3. Proceed to Fig. 4 and assume size of your rafters and radius of your haunch (if your frame is to have round knees). The rafter sizes in Fig. 4 are applicable to frames with straight knees.

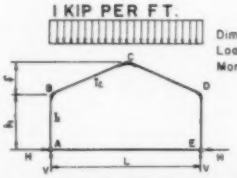
You now have a completed rigid frame with assumed sizes and shapes of members, all information necessary to make a typical cross section and a plan of your building. Lacking are your principal moments, shears and horizontal thrust. The *12-Minute Method* and a calculating machine will give you those results. The operation is self-explanatory and speedy. But you can easily err with your decimal points and your plus and minus signs. Watch them and your results will be 100% correct by the exact method. The calculations completed, it becomes a perfunctory matter to check for assumed member sizes and adjust them as desired.

General Notes

For bracing, use portals placed diagonally across

UNIFORM LOAD

1 KIP PER FT.



Dimensions are in feet
Loads are in kips
Moments are in ft. kips

COMPUTING OPERATIONS ARE NUMBERED (1)

FOR $\frac{I_2}{I_1}$ = 1 USE OPERATIONS (1) TO (31)

FOR $\frac{I_2}{I_1}$ = 1/2 USE OPERATIONS (1) TO (47)

UNIFORM LOAD $\frac{I_2}{I_1}$ = 1

OPERATION NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
OPERATIONS	L	h	f	(1)÷2	√(4)×(4)÷(3)×(3)	(3)÷(2)	5×(6)	(7)÷8	(1)×(1)	(8)×(9)	(2)÷(5)
EXAMPLE	125	25	15	62.5	64.275	0.6	3.0	11.0	15625.0	171875.0	0.389
SPACE FOR PRACTICE											
FOR YOUR REAL FRAME											

OPERATION NO.	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
OPERATIONS	3×(6)	(6)×(6)	(11)×(12)×(13)×3	32×(14)	(10)+(15)=M_b neg	(9)÷8	(6)×(16)neg	(16)+(17)+(18)=Mc	(16)÷(2)=H	(4)×V
EXAMPLE	1.8	0.360	5.549	177.568	−967.939	1953.125	−580.763	404.423	−38.718	62.5
SPACE FOR PRACTICE										
FOR YOUR REAL FRAME										

OPERATION NO.	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)
OPERATIONS	(1)+4	(19)+(4)	(16)÷(4) neg.	(22)+(23)−(24)	(4)−(25)	(25)÷2	(26)×(27)	(24)+(26)neg	(25)×(23)	(28)+(29)+(30)=Mx
EXAMPLE	31.25	6.4708	−15.487	53.2078	9.2922	26.6039	247.209	−143.908	344.297	447.598
SPACE FOR PRACTICE										
FOR YOUR REAL FRAME										

UNIFORM LOAD $\frac{I_2}{I_1}$ = 1/2

Don't forget to begin with operations (1) to (31) above then continue with operations (32) to (47)

OPERATION NO.	(32)	(33)	(34)	(35)	(36)	(37)	(38)	(39)
OPERATIONS	(11)÷2	(14)−(32)	(33)×32	(-1) (10)+(34)=M_b neg	(35)×(6)	(35)+(36)+(17)=Mc	(-1) (35)÷(2)=H	(37)÷(4)
EXAMPLE	0.194	5.355	171.360	−1003.01	−601.81	348.305	40.12	5.5729
SPACE FOR PRACTICE								
FOR YOUR REAL FRAME								

OPERATION NO.	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)
OPERATIONS	(35)÷(4)	(22)+(39)−(40)	(4)−(41)	(41)÷2	(42)×(43)	(40)×(42)	(41)×(39)	(44)+(45)+(46)=M_x
EXAMPLE	−16.048	52.871	9.6290	26.436	254.55	−154.53	294.64	394.66
SPACE FOR PRACTICE								
FOR YOUR REAL FRAME								

Mx = Max. Positive Moment

center of knee. Make them same depth as rafter; turn ends down to stay the compression flange of the knee. Use sway frames along ridge line for all spans 60 ft and greater. Sway frames may be purlins heavied up for lateral support with knee braces from purlins to bottom flange of rigid frame rafter; or, use built-up latticed members the same way. Space braced bays every fourth or fifth bay, and in those braced bays space the sway frames approximately same distance apart as spacing of bents. For buildings longer than 350 ft, use expansion joints with simple detail for purlins to slide.

For round knees use radial stiffeners to prevent inward bending of the compression flange if $b^2/tr > 1.2$ where b equals width of flange in inches, t equals thickness, r, radius in inches of bottom flange. The stability of the web may, however, control arrangement of the stiffeners. Assume neutral axis at one-quarter the distance along diagonal through center of knee.

For square knees, shear is critical within panel — not outside at column face as used frequently. Thus, diagonal stiffeners may be required besides those normal to column and rafter. And while they are usually overlooked in elastic design, you would not dare overlook them in plastic design. So learn now the need for stiffeners. The shearing stresses are considered as vertical and horizontal, entering the shear panel through the flanges. The principal stresses are naturally radial and circumferential. Assume the neutral axis located one-fifth the diagonal distance along center of knee.

For the foundations, avoid fixed bases except on rock or hardpan. Since pile foundations are known to move, partially fixed bases would be preferable to complete fixation. Avoid pins in hinged bases for economy and practicality. In most designs, standard flat narrow bars under flat base plates will function as hinges. There should, of course, be bar stops and premolded material or equal in space between base and bed plates. Specify grout pads, true and level, to be in place before arrival of steel columns. Keep rigid frame ties as nearly level as practicable; specify spacing to avoid catenaries.

Avoid field splices in knee. Weld all shop work. Use simplest details throughout design. Plan for the fullest duplication of rigid frames and mass production of identical units and details. All these spell economy. Other than the *12-Minute Method* given here, the remaining text of this short course is for the most part applicable to plastic design. When plastic design is studied and accepted more generally, an 8 min method will be available to replace the 12-min operations based on elastic design. It is worth studying.

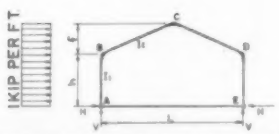
In conclusion, no math or method of analysis can replace wisdom compounded from common sense and balanced judgment, for the design of welded rigid frames.

Recommended Reading

"Welded Continuous Portal Frames." THE WELDING JOURNAL, July 1951, August 1951, November 1952; AISC publications on knees and plastic design; ASCE Proceedings, Separate 249, Vol. 79, "Rigid Frame Knees" by Olander.

WIND

Dimensions are in feet
Loads are in kips
Moments are in ft kips



WIND $\frac{I_2}{I_1} = 1$

OPERATION NO.	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	(56)	(57)	(58)
OPERATIONS	(2) ÷ (5)	(3) x (3)	(2) x (2)	(6) x 3	(51) ÷ 4	(49) x (52)	(48) x 2.5	(54) ÷ 6	(55) ÷ (51)	2 x (50) = (56)	(53) - (57)
EXAMPLE	0.38895	225.0	625.0	1.80	5.80	1305.0	0.97238	69724	8.7724	10965.5	-9660.5
SPACE FOR PRACTICE											
FOR YOUR REAL FRAME											

OPERATION NO.	(59)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(67)	(68)	(69)	(70)	(71)
OPERATIONS	(48) + (51)	(49) ÷ (50)	(59) + (60) + 3	(61) x 16	(58) ÷ (62)	(2) = (3)	(64) ÷ 2	(63) - (65) = M_D	(50) ÷ 4	(49) ÷ 4	(6) + 1	(66) + (65)	(69) x (70)
EXAMPLE	2.189	0.360	5.5490	88.784	-108.81	375.0	187.5	-296.31	156.25	56.25	1.60	-108.81	-174.10
SPACE FOR PRACTICE													
FOR YOUR REAL FRAME													

OPERATION NO.	(72)	(73)	(74)	(75)	(76)	(77)	(78)	(79)	(80)	(81)	(82)
OPERATIONS	(67) + (71)	(72) - (68) = M_C	(50) ÷ 2	(64) + (74)	(75) + (66) = M_B	(2) + (3)	(77) = (77)	(1) x 2	(-1) (78) ÷ (79) = V_A	(-1) (66) ÷ (2) = H_E	(81) - (77) = H_A
EXAMPLE	-17.850	-74.10	312.50	687.50	391.19	40.0	1600.0	250.0	- 6.40	11.852	- 28.148
SPACE FOR PRACTICE											
FOR YOUR REAL FRAME											

WIND $\frac{I_2}{I_1} = \frac{1}{2}$ USE OPERATIONS (48) to (97)

OPERATION NO.	(83)	(84)	(85)	(86)	(87)	(88)	(89)	(90)	(91)
OPERATIONS	1.25 x (48)	(56) - (83)	2 = (50) x (84)	(53) - (85)	(48) ÷ 2	(61) - (87)	16 x (88)	(86) ÷ (89)	(90) - (65) = M_D
EXAMPLE	0.48619	8.2862	10357.8	-9052.8	0.19448	5.3545	85.672	-105.67	-293.17
SPACE FOR PRACTICE									
FOR YOUR REAL FRAME									

OPERATION NO.	(92)	(93)	(94)	(95)	(96)	(97)
OPERATIONS	(90) x (69)	(67) - (68)	(93) + (92) = M_C	(91) + (75) = M_B	(-1) x (91) ÷ (2) = H_E	(96) - (77) = H_A
EXAMPLE	-169.07	100.0	-69.070	394.33	11.727	-28.273
SPACE FOR PRACTICE						
FOR YOUR REAL FRAME						

Fig. 7 12-Minute Method

JOINT DESIGN FOR MAKING ROOT-PASS WELDS WITHOUT FILLER METAL

New joint design described as providing an economical means for making sound root-pass welds without use of backing rings in stainless steel, killed steel and aluminum piping

BY L. C. LEMON AND W. R. SMITH

ABSTRACT. The fabricating industry has been searching for several years for methods of making root-pass welds without the use of backing rings. A joint was designed and a technique developed for making root-pass welds by the inert-gas tungsten-arc process without the addition of filler metal. This method produces a uniform full penetration weld reinforcement on the far side of the joint in all positions of welding. Visual inspection of the near side of the root pass readily indicates the weld penetration and uniformity of the weld reinforcement on the far side of the weld. Fit-up tolerances and welding current are not critical and a minimum of welder skills are required.

This paper includes a detailed description of the joint design and welding technique employed to produce root passes without the addition of filler metal. Schematic drawings and photographs are employed to demonstrate the joint design.

Introduction

The fabricating industry has been searching for several years for an economical, dependable and practical joint design and welding technique for making pipe butt joints in steel and stainless steel piping without the use of backing rings. The fabrication of equipment and piping systems for atomic energy applications where highly corrosive radioactive solutions must be contained has increased the need for such a joint.

Requirements for a root pass are:

1. That it have complete penetration and uniform weld reinforcement on far side of the joint in all positions of welding, with no danger of burn-through.
2. That a visual inspection of the near side of the root pass will indicate the completeness and uniformity of penetration.
3. That the joint be made economically with minimum welder skills required in all positions of welding.

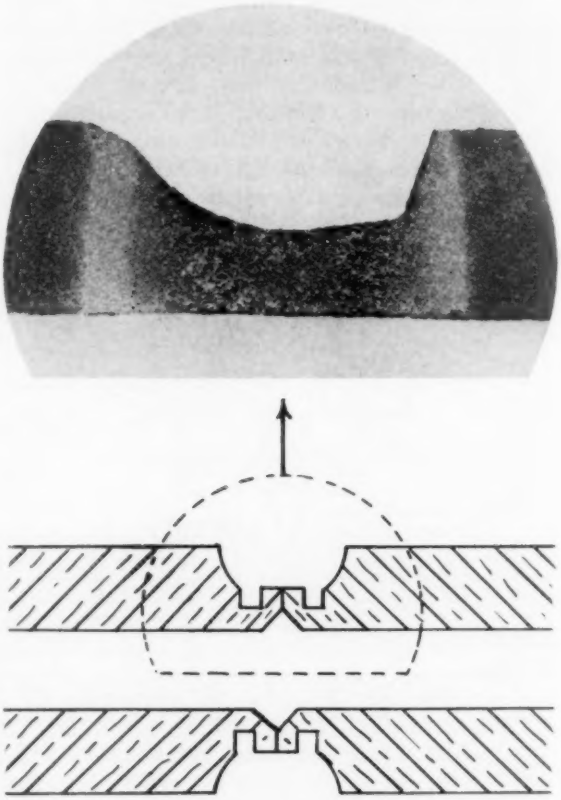


Fig. 1 Idealized drawing of the G. E. joint with a photomacrograph showing penetration and quality of the root pass in carbon steel pipe after welding

An investigation was initiated to evaluate some of the designs, techniques and methods which have been employed with some degree of success and to develop new methods if it was found necessary.

Recent investigators[1–5] have all concluded that the inert-gas tungsten-arc welding process is the best process to be employed for making root passes without backing rings. These investigators have also demonstrated that an inert-gas backup or purge is required

L. C. Lemon is Engineer, General Electric Co., Hanford Atomic Products Operation, Richland, Washington, and **W. R. Smith** is Specialist, Materials and Welding, General Electric Co., Atomic Power Equipment Dept., San Jose, Calif.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12, 1957.

Work Performed under Contract No. W-31-109-Eng-52 between the Atomic Energy Commission and General Electric Co.

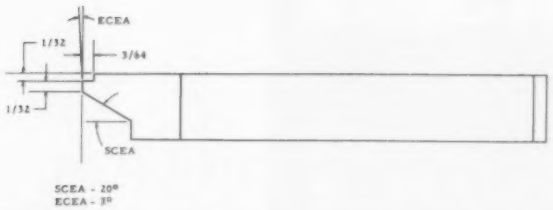


Fig. 2 Cutting tool for fabrication of G. E. joints on pipe and tubing with wall thicknesses from $^1/_8$ to $^1/_4$ in.

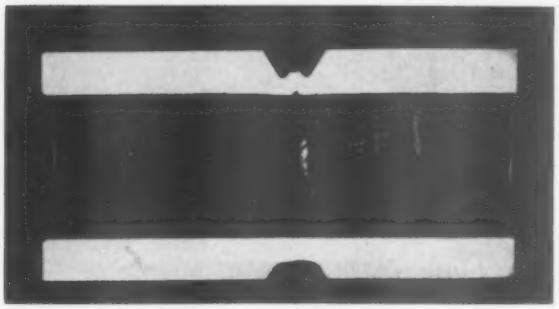


Fig. 3 One-inch, schedule 160, Type 304 stainless steel pipe showing the G. E. joint preparation and root-pass weld. The bottom of the specimen was in the overhead position when it was welded. X1

Fig. 4 Cross section of a 3-in., schedule 40, Type 304 stainless steel pipe. Otherwise same as Fig. 1. Note difference in detail of joint

for making root passes in stainless steel when using the inert-gas tungsten-arc welding process if a smooth, uniform and unoxidized surface is to be obtained on the far side of the weld. Dry nitrogen, helium or argon appear to be effective gas purges for stainless steel. Some of the investigators indicate that a helium or argon backup is required on carbon or low-alloy steels, but others indicate that none is required. This investigation appeared to confirm most of the conclusions which the other investigators had reached and emphasis was placed on the evaluation of joint preparations and welding techniques.

A joint with special preparations of the root edges, which had seen limited use in the Materials and Processes Laboratory of the Large Steam Turbine and Generator Division of the General Electric Co., appeared to have great potential in the initial comparison, and efforts were directed to develop and evaluate this joint for several materials and applications. For convenience of identification this joint will be identified as the G. E. joint.

Discussion

Joint Design

The G. E. joint preparation consists of machining the root edges to the general configuration shown in Fig. 1. The raised edges on the near side of the joint provide the metal required to replace the metal which was removed in forming the small bevels on the far side. This joint geometry provides for a weld bead in which the surface tension forces are sufficient to overcome the gravitational forces in all positions of welding. As a result of these conditions, complete and uniform penetration is consistently obtained in all positions of welding of steel and stainless steels with no tendency for burning through or falling out within a wide range of welding conditions.

Figure 2 is a drawing of a cutting tool suitable for preparing joints on piping with wall thicknesses from $^1/_8$ to $^1/_4$ in. For piping with thicker walls, the dimension of the tool may be increased to $^1/_{16}$ and $^3/_{32}$ in. Multiple tools in a turret head appear to be more satisfactory for providing the joint configuration than are form cutting tools.

Results

The dimensions of the joint are not critical and a large tolerance is permissible in the actual dimensions of the joint configuration. Figures 3, 4, 5, 6 and 7 show the cross sections of a variety of sizes, materials and joint dimensions. Figure 8 demonstrates the offset which can be tolerated and Fig. 9 shows a G. E. joint prepared on the end of one pipe joined to a pipe which was prepared with a standard bevel and a small root bevel on the far side. The size and shape of the weld bead on the near side of the weld serves as an indication of the completeness and uniformity of the weld reinforcement on the far side and the root pass can be inspected before subsequent weld passes are made by any other acceptable welding process.

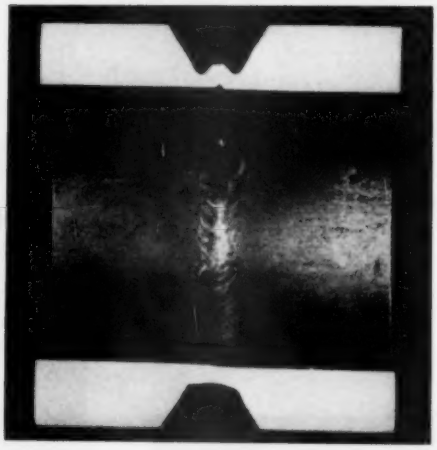


Fig. 6 Cross section of 2-in., schedule 160, low-carbon steel pipe

Fig. 5 Cross section of a 3-in., schedule 40, low-carbon steel pipe

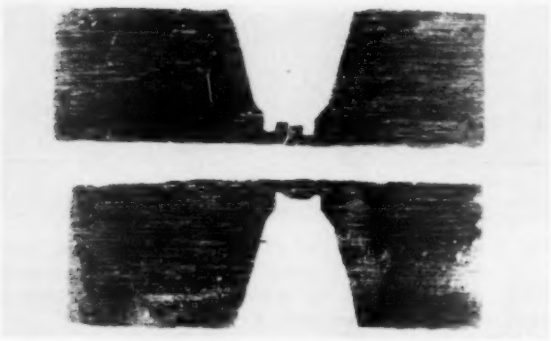
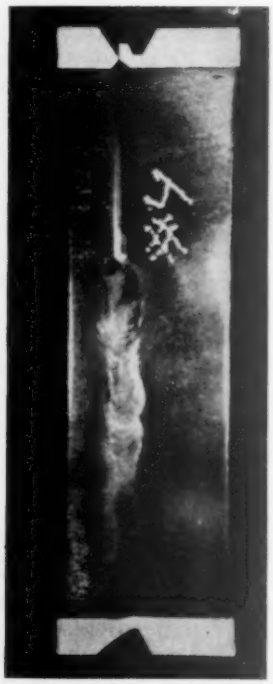


Fig. 7 Cross sections of 8-in., schedule 160, low-carbon steel pipe

Fig. 8 Cross section of 3-in., schedule 40, Type 304 stainless steel pipe demonstrating the offset which is tolerable with the G. E. joint

Fig. 9 Cross section of 3-in., schedule 40, Type 304 stainless steel pipe demonstrating the jointing of a 37 1/2 deg bevel joint to a G. E. joint



Some of the low-carbon steel welds were made without a gas backup and they appeared to be as sound and as easily welded as those welds made with argon or helium backup. It is considered that more experimental work must be performed to actually determine if a backup gas is required on low-carbon steel and what grades of steel can be welded by the inert-gas tungsten-arc process. This joint has been employed successfully for joining aluminum piping and it is considered that it can be employed for other metals and alloys.

Conclusions

This joint design provides an economical means for making sound root-pass welds in piping without the use of backing rings in stainless steel, killed steel and aluminum piping. The joint also appears to satisfy the requirements outlined above and it should provide fabricators with another means to solve a fabricating problem.

Bibliography

1. Mueller, R. A., and Root, W. B., "Inert-Arc Welding Technique for Eliminating Backing Rings in Piping," The Welding Journal, **32** (3), 205 (1953).
2. Pilia, F. J., "Inert-Tungsten Arc Welding of Stainless Steel Piping," *Ibid.*, **32** (12), 1167 (1953).
3. Pursell, R. T., "Inert-Arc Field Welding of Pressure Piping," *Ibid.*, **33** (1), 41 (1954).
4. Risch, T. A., and Dohna, A. E., "Consumable Insert Method of Root Pass Welding," *Ibid.*, **33** (6), 670 (1954).
5. Pursell, R. T., "Joint Detail in Inert Arc Welding of Pressure Piping," *Ibid.*, **34** (8), 747 (1955).

PERIPHERAL WELDING OF INTERNALLY-CLAD STEEL FOR NUCLEAR REACTOR APPLICATION

Authors describe special procedures developed for welding spherical pressure-vessel shell made of carbon-steel plate clad with Type 347 stainless steel

BY W. LEONARD AND J. C. THOMPSON, JR.

Introduction

Weldments in stainless-clad steel are not new as many successful and recommended procedures and techniques are in use today. The problems encountered during welding of clad steels and the advisability of preheat or postheat treatment vary with each individual situation such as: the welding characteristics of each metal, the metallurgical properties and compatibility of the two base metals, the accessibility to the joint and the joint design. All of these factors ultimately determine the most desirable welding process and procedure.

The problem of fusion-line and weld-metal cracking when depositing stainless steel on carbon steel or carbon steel on stainless-steel base metal, is often encountered in the welding of clad materials. For example, carbon-steel weld beads deposited on an austenitic stainless-steel base plate will usually result in cracking. This is caused by the dilution of the weld metal with the base metal resulting from the heat input required for normal penetration. The converse is not true; an austenitic stainless-steel weld bead on a carbon-steel base plate with controlled dilution does not normally result in cracking. This can be explained metallurgically by an examination of the iron, nickel, chromium phase diagram at various carbon levels. These resulting metallurgical structures from weld metal-base metal mixing can be estimated with the aid of the Schaeffler[1, 2] diagram. Also, the dilution of the stainless-steel cladding by the less corrosion-resistant metal often results in an alloy of sufficiently lowered corrosion resistance that is inadequate for the intended service. For brevity and simplicity it might be summarized by saying that the major part of the diluted metal in carbon-steel weld bead consists of a nonductile phase, martensite, which cracks due to the thermal stresses encountered during cooling. The major part of the diluted metal in an austenitic stainless steel 25–20 weld bead is a relatively ductile constituent, austenite, which can withstand the thermal stress imposed during cooling from the solidification temperature without cracking. This allows one method of avoiding fusion-line and weld-metal cracking in stainless-steel-clad carbon-steel plates; commonly referred to as back chipping.

A single V or U joint is usually made with the land extending above the clad and into the carbon steel. Carbon-steel weld metal is deposited from the carbon-steel surface. Sufficient land is allowed so that the first carbon-steel pass will just fall short of penetrating to the stainless clad. The bottom of the carbon-steel root pass is then chipped or ground out from the clad side of the plate and stainless-steel weld metal is then deposited from the same side to complete the weld joint. It can be seen that, in this procedure, carbon-steel weld metal was never placed on stainless steel, and that the first few passes of stainless steel were deposited on carbon steel. This method of welding is also used to combat the second problem of lowered corrosion resistance in claddings where dilution would normally be located near the bottom surface. The juncture of the two weld metals can be moved to the interior of the plate by design or a void may be left between the two dissimilar weld metals. A great deal of latitude and individual variations in details of welding is permitted by using this or modifications of this method.

In many designs of interior-clad pressure vessels or piping, access for welding is permitted from one side only—the outer surface. Since back chipping is not possible, an alternate welding procedure for producing the desired weldment must be developed. This then

W. J. Leonard is Metallurgist, Oak Ridge National Laboratories, Oak Ridge, Tenn., and **J. C. Thompson, Jr.**, is Mechanical Inspection Supervisor, Union Carbide Nuclear Co., Y-12 Plant, Oak Ridge, Tenn.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Table 1—Certified Analysis and Mechanical Properties of 25% Stainless-Clad–Si-Killed Firebox Steel Specifications A201 Grade A Base Metal Used in Test Weldments

Melt No.	Slab No.	Chemical analysis, %*								Mechanical properties		
		C	Mn	P	Si	S	Cr	Ni	Cb	Yield point, psi	Tensile strength, psi	% Elongation
12187	8	0.14	0.40	0.017	0.21	0.033	...	...	...	...	62,800	..
59046	1C	0.058	1.44	0.023	0.049	0.013	18.12	12.11	0.68	40,600	64,100	27

Homogeneity tests satisfactory. Bend tests satisfactory.
* Provided by the mill.

is the problem that is investigated and reported in this paper.

Welding Procedure Investigation

Since the root pass must necessarily be stainless steel, any initial carbon-steel weld deposits would have to be made on stainless steel. One alternative would be the use of stainless-steel filler metal for the entire thickness of the welding groove, but since a process for welding plates of thicknesses up to 5 in. was desirable, this was considered impractical and uneconomical.

Two basic joints were proposed with variations in design and filler metals which resulted in investigation of four different methods for welding as follows:

Method 1: Type 347 stainless-steel weld metal was deposited to a level just above the carbon-steel–stainless-steel interface. The face of the weld deposit was then machined flat and even with the interface and covered with an ingot-iron strip approximately $^1/_{16}$ in. thick. The strip was tack welded to the carbon steel leaving a lamination between the stainless steel and ingot iron. Carbon-steel weld metal was used to complete the weldment.

Method 2: Type 347 stainless weld metal was deposited in the groove up to the stainless-steel–carbon-steel interface. Type 310 stainless-steel weld metal one layer thick was then deposited, followed in turn by one layer of ingot-iron weld metal. The weldment was then completed with carbon-steel weld metal.

Method 3: Type 347 stainless-steel weld metal was deposited in the groove to a point slightly below the stainless-steel–carbon-steel interface followed by two layers of Type 308L stainless-steel weld metal to approximately $^1/_{16}$ in. above the interface. One layer of ingot iron was then deposited over the 308L weld metal and the remainder of the weldment was completed with carbon-steel weld metal.

Method 4: The same procedure was used as in the third method, except that ingot iron was omitted. This resulted in depositing carbon-steel weld metal directly on Type 308L stainless-steel weld metal. The weldment was completed with carbon-steel weld metal as in the previous joints.

These four methods had the objective of preventing cracking in the interface area by (1) mechanically separating the carbon-steel and stainless-steel weld metal or (2) having intermediate layers of weld metal which could be successfully deposited on the Type 347 stainless-steel weld metal; which in turn permitted the deposition of carbon-steel weld metal on the top layer of the transition weld metal.

Materials

Base Metal: The pressure-vessel shell for the nuclear reactor was designed of 4-in. thick carbon steel (ASTM A212 Grade B) clad with a 10% thickness of Type 347 stainless steel on the interior.

Since material of this type was not available for weld procedure investigation, 1-in. thick carbon-steel plate (ASTM A201 Grade A) roll clad with a 20% thickness of Type 347 fully austenitic stainless steel was used. The chemical and mechanical properties of the steel are given in Table 1.

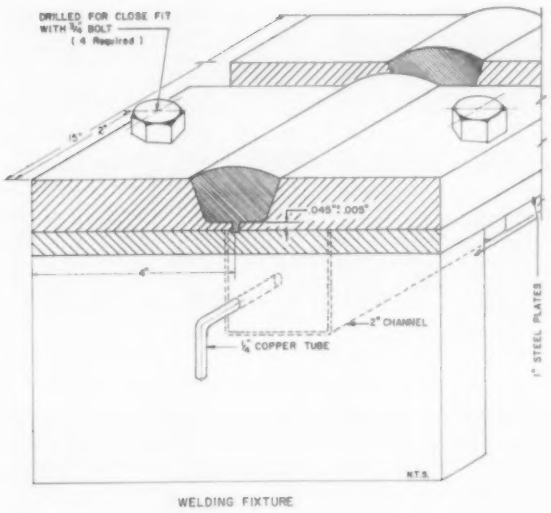
Weld Filler Metals: Table 2 summarizes the chemical analysis of the welding rod and electrodes used with exception of the ingot iron which was of commercial grade and the low-hydrogen carbon-steel electrodes conforming to A316–48T, E7015 and E7016.

Types 310 and 347 stainless-steel electrodes con-

Table 2—Chemical Analysis of Filler Rod and Electrode Used in Test Weldments

Classification	Heat No.	Chemical analysis, %‡								
		C	Mn	P	Si	S	Cr	Ni	Cb	Mo
ER347	E3453L347*	0.06	1.83	0.030	0.6	0.015	20.28	10.24	0.79	...
E308L	G75322X	0.03	2.00	0.025	0.45	0.010	20.57	10.25	...	Trace
E347–15	4J5A	0.04	1.51	0.023	0.25	0.007	21.35	10.31	...	...
E347–15	4J5A†	0.078	1.42	0.030	0.35	0.83	20.24	10.80	0.17	0.83
E310–16	2X8200	0.115	1.84	0.020	0.28	0.010	27.23	21.42	...	...
E7015	.....	...	...	...	...	...	...	...	...	...
E7016	.....	...	...	...	...	...	...	...	...	...

* EB insert.
† Weld metal analysis (others are core wire analysis).
‡ Provided by supplier.



WELDING FIXTURE

Fig. 1 Welding fixture

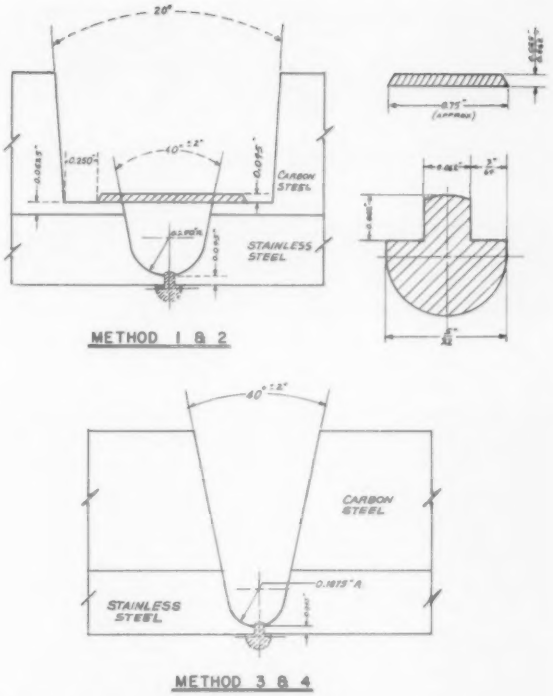


Fig. 2 Joint designs used in welding

Fig. 3 Root-pass crack resulting from high heat input

formed to A298–48T, E310–16 and E347–15. Type 347 stainless-steel rod, EB insert 2, conformed to A371–53T, ER347. Type 308L stainless steel electrodes conformed to A298–55T, E308–15.

To minimize the possibility of cracking, all stainless-steel filler metal, with exception of the Type 310 electrode which was fully austenitic, contained 5 to 8% ferrite as determined by Schaeffler diagram.

Equipment

To meet the quality requirements of weld joints which are required in nuclear reactors, the root pass is made by the inert-gas-shielded tungsten-arc process. In addition, the back side or internal surface of such weldments is blanketed by inert gas. A welding fixture was built to provide gas coverage to the back or bottom side of the test plates. This fixture is shown in Fig. 1, and was fabricated from 1-in.-thick carbon-steel plate with a 2-in. steel channel to contain the inert gas. Four $^{3}/_{4}$-in. diam bolts were used to maintain firm contact between the test plate and the fixture. These bolts also restrained the weldment thereby reducing warpage.

A 200-amp selenium rectifier welding machine was used as a source of welding current. To reduce arc craters and microcracks when extinguishing the tungsten arc, the machine was equipped with a foot-operated remote control unit complete with microswitch for contactor control.

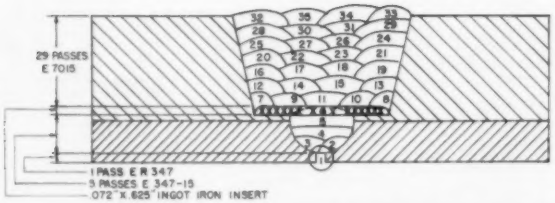
A standard water-cooled, inert-gas-shielded torch rated at 250 amp was used for making the tungsten-arc passes in the manual welded test plates.

Preparation of Test Plates

Six test joints utilizing the joint designs as shown in Fig. 2, were prepared for welding in the 1G flat position. The test plate dimensions were 1 x 8 x 15 in. Test plate surfaces, with exception of the weld joint, were wire brushed and then degreased in a vapor degreaser. The Type ER347 EB insert was placed in the joint and tack welded at 3-in. intervals. The plates were then bolted to the fixture and sealed, so that the blanket purge gas could escape only through the weld joint and the escape hole left at one end of the fixture.

Welding Speed

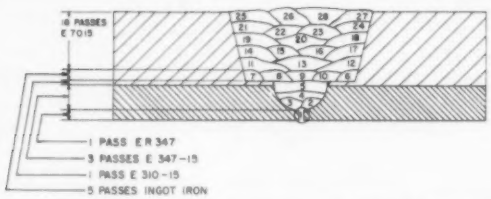
Previous experience in qualification of procedures with the preplaced ER347 insert indicated that additional information was needed relative to heat input at various amperage levels for materials exceeding $^{1}/_{2}$ in. in thickness; therefore, amperage was varied from a minimum of 90 amp to a maximum of 140 amp. Torch travel speed was varied from 1 to 4.5 ipm. These manipulations allowed the control of heat input per pass thus regulating the resulting penetration and dilution. At each amperage level used, a heat input



PASS NO.	FILLER METAL	D.C. CURRENT			WELDING SPEED I PM	INERT GAS TUNGSTEN ARC			
		POLARITY	AMPS	VOLTS		TUNGSTEN SIZE	TORCH CUP SIZE*	ARGON FLOW CFH TORCH	ARGON FLOW CFH BACK-UP
1	5/32" ER347	STRAIGHT	140	15	4	3/32"	8	15	15
2-4	1/8" E 347-15	REVERSE	85	25	5-6	—	—	—	15
5-6	1/8" E 347-15	REVERSE	90	25	3.5	—	—	—	—
	MACHINED FLAT 1/16" ABOVE INTERFACE AND INSERTED INGOT IRON .072" x .625"								
7-15	1/8" E 7015	REVERSE	105-110	25	7-12	—	—	—	—
15-33	1/8" E 7015	REVERSE	130	25	5-7	—	—	—	—

*16 th of an inch

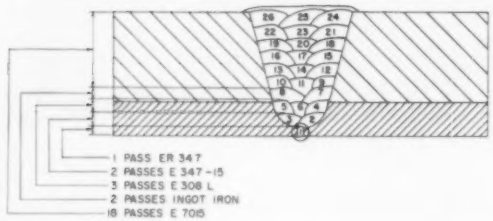
Fig. 4 Weld test data, Method 1



PASS NO.	FILLER METAL	D C CURRENT			WELDING SPEED I PM	INERT GAS TUNGSTEN ARC			
		POLARITY	AMPS	VOLTS		TUNGSTEN SIZE	TORCH CUP SIZE*	ARGON FLOW CFH TORCH	ARGON FLOW CFH BACK-UP
1	5/32" E R 347	STRAIGHT	120	13	4	5/32"	8	15	15
2-3	1/8" E 347-15	REVERSE	85 X95	25	5	—	—	—	—
4	1/8" E 347-15	REVERSE	95	25	3	—	—	—	—
5	1/8" E 310-15	REVERSE	100	25	3	—	—	—	—
6-10	3/64" INGOT IRON STRIPS	STRAIGHT	185	19	2-3	3/32"	7	25	—
11-28	1/8" E 7015	REVERSE	120-130	25	4-7	—	—	—	—

* 16th of an inch

Fig. 5 Weld test data, Method 2



PASS NO.	FILLER METAL	D C CURRENT			WELDING SPEED I PM	INERT GAS TUNGSTEN ARC			
		POLARITY	AMPS	VOLTS		TUNGSTEN SIZE	TORCH CUP SIZE*	ARGON FLOW CFH TORCH	ARGON FLOW CFH BACK-UP
1	5/32" ER 347	STRAIGHT	140	15	4	3/32"	8	15	15
2-3	1/8" E 347-15	REVERSE	85	25	7	—	—	—	—
4-6	1/8" E 308 L	REVERSE	100	24	5	—	—	—	—
7-8	3/64" INGOT IRON STRIPS	STRAIGHT	185	20	2-3	3/32"	7	25	—
9-26	1/8" E 7015	REVERSE	130	25	5-7	—	—	—	—

* 16 th of an inch

Fig. 6 Weld test data, Method 3

over a certain critical value resulted in cracking of the root pass (see Fig. 3). At 140 amp welding current, a minimum welding speed of 4 ipm must be maintained to secure a sound root pass. At 90 amp, a speed of 1 ipm or greater resulted in sound welds. At lower amperages, travel speed was less critical due to greater heat dissipation through the base plate. All root passes that cracked in the test weldments were ground out and rewelded.

Welding Details of Test Joints

The tungsten-arc weld passes in all test joints were made by a welding operator who was certified for manual tungsten-arc welding of austenitic stainless steels. The remaining coated-electrode passes were made by a welding operator who was certified for coated metal-arc welding of carbon steel and austenitic stainless steels.

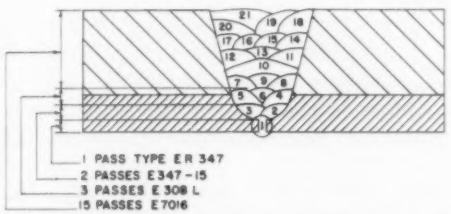
Four test joints were welded to completion as shown by the welding procedure test data for each method (see Figs. 4, 5, 6 and 7).

The two additional joints were used for the investigation of proper welding speeds for the EB insert and repair techniques.

No preheat or postheat was used in making any of the test weldments and interpass temperature did not exceed 200° F.

Method 1: The desired thickness of the ingot-iron insert for Method 1, Fig. 4, was not available in one thickness so two thicknesses of the 3/64-in. ingot-iron sheet were sheared into approximately 3/4-in. wide strips, sandblasted, degreased and spot welded together. After the Type 347 stainless-steel filler metal was machined back to the carbon-steel–stainless-steel interface in the joint, the insert was placed in intimate contact with the joint and tack welded to the carbon steel at 1/2-in. intervals. Some difficulty from burn-through was encountered while depositing the low-hydrogen electrode over the insert. This was due to expansion and warpage in the center of the insert which tended to pull away from the joint even though a back-step welding technique was employed.

Methods 2 and 3: Ingot-iron filler metal for deposition by the tungsten-arc welding process as used in Methods 2 and 3 (see Figs. 5 and 6) was cut from the 3/64-in. thick ingot-iron sheet. Prior to deposition of the ingot-iron filler metal, the surfaces of the previously deposited Type 308L or 310 stainless-steel electrode were hand ground with a "Carboloy" steel



PASS NO.	FILLER METAL	D.C. CURRENT			WELDING SPEED I PM	INERT GAS TUNGSTEN ARC			
		POLARITY	AMPS	VOLTS		TUNGSTEN SIZE	TORCH CUP SIZE*	ARGON FLOW CFH TORCH	ARGON FLOW CFH BACK-UP
1	5/32" ER 347	STRAIGHT	95	10	1	5/32"	8	15	15
2-3	1/8" E 347-15	REVERSE	85	25	7	—	—	—	—
4-6	1/8" E 308 L	REVERSE	90	25	5	—	—	—	—
7-21	1/8" E 7016	REVERSE	100-120	25	3-5	RODS DRIED TO 350°F			

* 16th of an inch

Fig. 7 Weld test data, Method 4

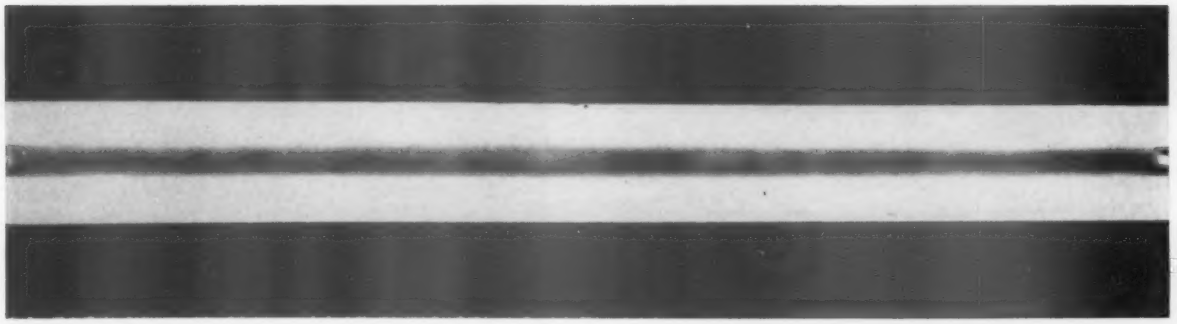


Fig. 8 Radiograph showing crack in root pass

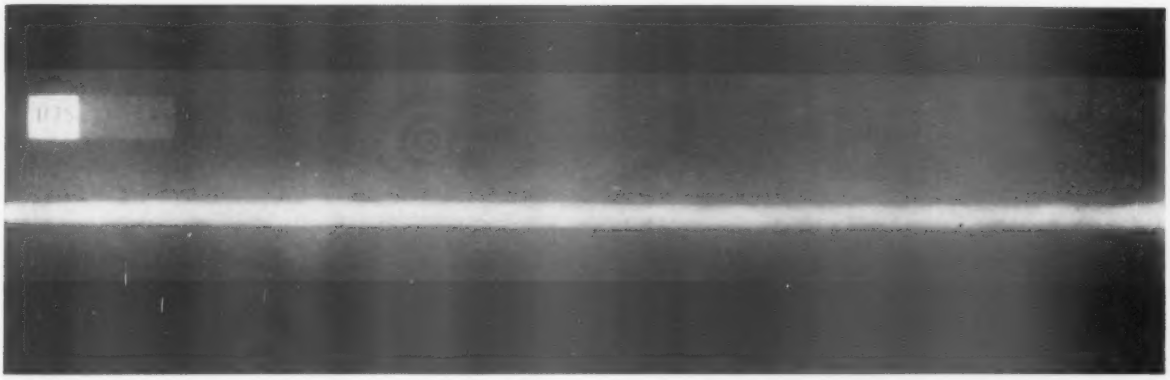


Fig. 9 Radiograph of completed weldment, Method 1

burr to remove all surface irregularities. To prevent deep penetration and excessive dilution an overlay or hard surfacing welding technique was used in depositing the ingot iron. No difficulties were experienced during this operation.

Method 4: The welding procedure for Method 4 (see Fig. 7) is the same as Method 3 (see Fig. 6) except the ingot-iron weld deposit was omitted. The 7016 low-hydrogen carbon-steel weld metal was deposited directly on the Type 308L stainless-steel weld metal. Some difficulty from porosity along the edge of the weld was experienced and the deposit tended to be more convex than normally encountered when welding on a carbon-steel base metal.

The low-hydrogen Type E7015 and E7016 carbon-steel electrodes were dehydrated for 24 hr at 350° F prior to welding operations. A short arc was maintained and all passes were of stringer type except pass No. 10 in Method 4 (see Fig. 7). Even though the E7015 electrode had better operating characteristics, difficulty with porosity was encountered with both types of electrodes. Each pass was wire brushed with a carbon-steel brush. Surface irregularities and craters were hand ground using a "Carboloy" steel burr in an air-operated tool grinder.

All stainless-steel welding passes were of stringer type with a short arc being maintained at all times. Each pass was wire brushed with a stainless-steel brush. Surface irregularities and craters were hand ground using a "Carboloy" steel burr in an air-operated tool grinder.

Inspection of Weldments

The quality required for the test weldments was as follows:

1. No defects such as porosity, inclusions, cracks, lack of fusion, incomplete penetration or tungsten contamination were allowed in the stainless clad portion of the weldment. The root pass "push-through" or reinforcement could not exceed $^1/_{16}$ in. in height and must be uniform in contour.

2. The completed weldment could have no defects such as cracks, lack of fusion, incomplete penetration or tungsten contamination. Porosity, slag or other inclusions greater than size medium for the thickness of plate being welded or in excess of half the amount permitted by the porosity standards of the 1952 ASME Code were not permitted.

To meet these requirements:

1. Each weld pass was visually inspected using 5 to 10 power magnification.

2. Liquid dye penetrant was used for the root pass, at the stainless-steel–carbon-steel interface and upon completion after the weld surface was ground smooth.

3. X-ray was used for the root pass, as shown in Fig. 8, at the stainless-steel–carbon-steel interface and upon completion of the weld, as shown in Fig. 9. Radiographic techniques conformed to UW51 of the 1952

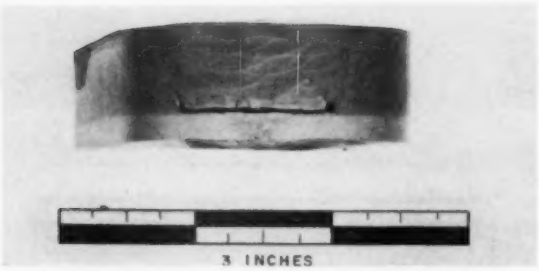


Fig. 10 Transverse side-bend specimen, Method 1

Fig. 11 Transverse side-bend specimen, Method 2

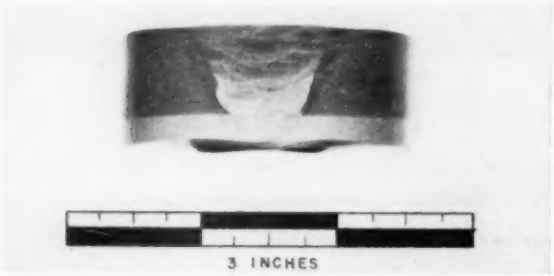


Fig. 12 Transverse side-bend specimen, Method 3

Fig. 13 Transverse side-bend specimen, Method 4

ASME Code for Unfired Pressure Vessels.

All defects exceeding the permissible limits were repaired by grinding or grinding and rewelding and reinspected.

All test weldments passed X-ray inspection at the stainless-steel–carbon-steel interface level. Upon completion, Method 1 (see Fig. 4) failed to pass inspection due to slag inclusions and porosity. Methods 2, 3 and

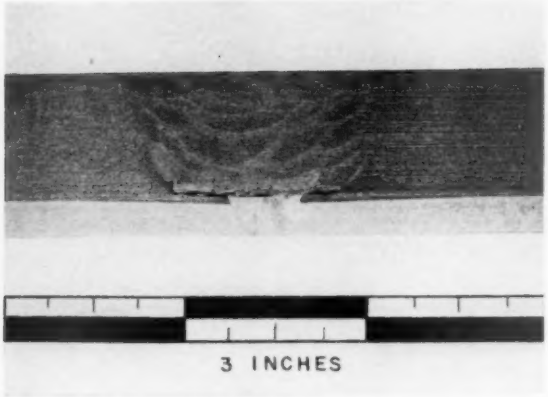


Fig. 14 Macro specimen, Method 1

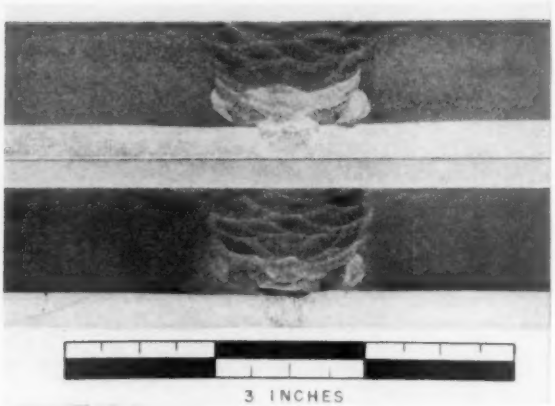


Fig. 15 Macro specimen, Method 2

4 (see Figs. 5, 6 and 7) were acceptable although all three exhibited porosity. Method 2 (see Fig. 5) was the highest quality weldment with only scattered, very minute porosity being observed.

Bend Test

Standard transverse side bend coupons $^{3}/_{8}$ x 1 x 8 in. were removed from all four weldments. Specimens, etched after bending to show the weld passes, are shown in Figs. 10, 11, 12 and 13.

Method 1: Of ten specimens tested only two bent 180°. The remaining eight failed by complete fracture before reaching 180°. One of the two specimens that bent 180° was rejected for fractures exceeding $^{1}/_{8}$ in. Practically all the fractures were initiated by the notch effect introduced by the ingot-iron insert as illustrated in Fig. 10.

Method 2: Of ten specimens tested, nine bent 180°. One failed by complete fracture before reaching 180°. Three were rejected for fractures exceeding $^{1}/_{8}$ in. Six specimens were acceptable with four being free of defects. All fractures occurred in the Type 310–ingot-iron transition zone.

In all specimens dilution of the ingot-iron weld metal and carbon-steel weld metal in the transition zone caused the weld metal to kink or pull away from

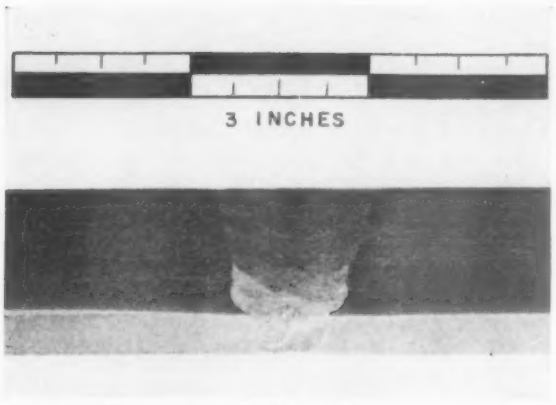


Fig. 16 Macro specimen, Method 3

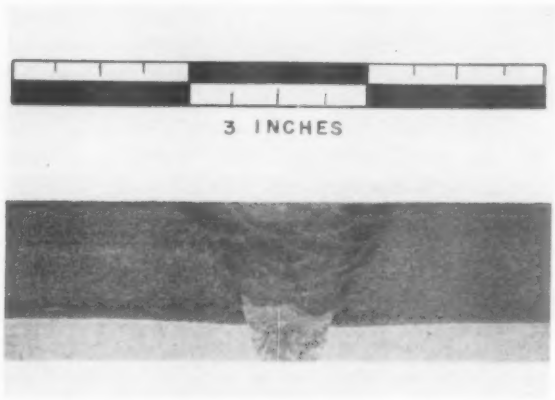


Fig. 17 Macro specimen, Method 4

the base metal during bending. A typical bend test is shown in Fig. 11. The iron-to-stainless steel interfaces did not show this effect.

Method 3: Fourteen specimens were tested, all bent 180°. Seven were rejected for fractures exceeding $^1/_8$ in. Seven specimens were acceptable with one being free of defects. All fractures occurred in the Type 308L ingot-iron transition zone.

Some kinking effect was noted in all specimens as shown in Fig. 12. The iron-to-stainless steel interfaces did not show this effect.

Method 4: Fourteen specimens were tested, all bent 180° and were acceptable. One specimen was free of defects and the largest fracture noted did not exceed $^1/_8$ in. as shown in Fig. 13. The remaining defects were classed as minute with only one exceeding $^1/_{64}$ in. in length. All defects occurred in the Type 308L low-hydrogen steel transition zone.

A summary of bend test results is shown in Table 3.

Macroscopic Examination

Figures 14, 15, 16 and 17 show macrosections taken from welds produced by all four methods. All were acceptable except that produced by Method 1 (see Fig. 14). The stainless steel, intermediate and carbon-steel beads are all clearly outlined, showing the dilution and differential compositions obtained by the various welding methods.

Microscopic Examination

Metallographic examination of the specimens taken from each of the four weldments indicated normal dilution expected in welds between stainless-steel and carbon-steel materials. In Method 1 weld sample, the iron strip prevented dilution between the dissimilar weld metals. Dilution of the Type 347 stainless-steel weld metal below the strip by the carbon-steel base metal was normal as was dilution of carbon-steel weld metal by the carbon-steel base metal. As this method was obviously unsatisfactory, due to unsoundness and the bend test failure, no detailed examination was performed. Microhardness surveys of the weld and adjacent area were made on specimens produced by the other three methods.

In Method 2 weld sample (see Fig. 18), the 347 weld metal had an average hardness of 210 VPN; the Type 310, 230 VPN; the carbon steel 195 VPN. Traverse hardness readings made at the center line of the weld metal from the underlying Type 310 weld metal into the ingot-iron weld metal gave a hardness of 240 VPN on the undiluted Type 310 at the juncture, and a hardness of 383 VPN on the adjacent ingot iron diluted with Type 310 metal. The traverses from Type 310

Table 3—Mechanical Properties of Test Coupons Taken from Test Weldments

	*Tensile tests***				*Guided side bends** transverse to weld‡*	
	Tensile strength	*Elongation, % in 1¼ in.*				
Method	*composite, psi*	*Carbon steel*	*Stainless steel*	*Failure**	*No. of specimens*	*Results§*
1	79,200	12.5	20	HAZ	1	OK
	80,100	10	20	HAZ	9	NG
2	83,900		17	HAZ	4	NG
	83,400		17	HAZ	6	OK
3	78,900	8.7	21	HAZ	7	OK
	79,500	15	20	HAZ	7	OK
4	85,700	20†	25†	HAZ	14	OK

* HAZ—heat-affected zone.
† Gage length, ¾ in.
‡ All specimens bend to 180° or complete fracture.
§ Specimens evaluated in accordance with Sec. IX ASME Code coupons having fractures exceeding $^1/_8$ in. were rejected (NG).
** Figures are for as-welded condition. No preheat or postheat.

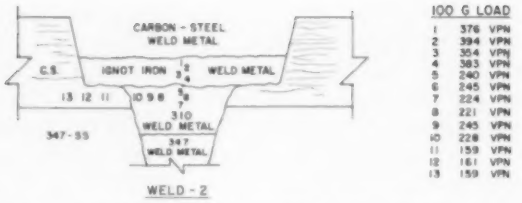


Fig. 18 Microhardness survey plots of typical welds

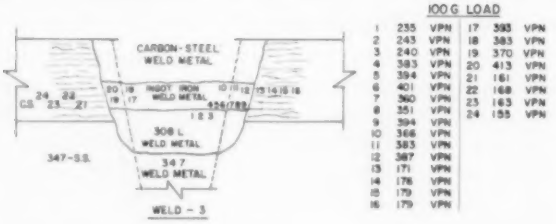


Fig. 19 Microhardness survey plots of typical welds

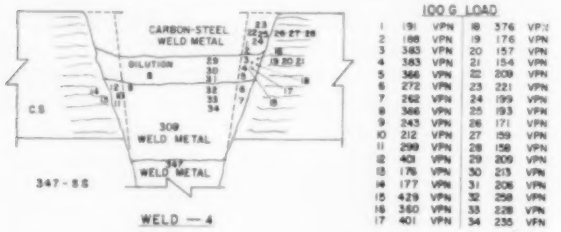


Fig. 20 Microhardness survey plots of typical welds

and carbon-steel weld metal into carbon-steel base metal indicated results normally obtained in dissimilar welding procedures. The ingot-iron weld metal diluted with Type 310 stainless steel had an average hardness of 375 VPN and microstructure similar to a 15% chromium–2% nickel martensitic stainless steel.

In Method 3 weld sample (see Fig. 19), the Type 308L weld metal had an average hardness of 240 VPN, which value it maintained at the juncture of the ingot-iron weld metal. The ingot-iron weld metal diluted with 308L metal had an average hardness of 390 VPN. The carbon-steel weld metal overlying this layer was further diluted by ingot-iron weld metal and had an average hardness of 370 VPN. A traverse made from this layer into the carbon-steel base metal gave a hardness of 387 VPN on the weld-metal side, 175 VPN average in the heat-affected zone of the base metal and 160 VPN in the base metal. A similar traverse across the weld-metal layer directly beneath consisting of diluted ingot iron and 308L weld metal (average 390 VPN), indicated a very narrow martensitic constituent at the base metal junction with a hardness of 413 VPN. The base metal and base-metal heat-affected zone were the same as above.

A traverse made at a position where the ingot iron and Type 308L diluted weld metal inadvertently penetrated into the Type 347 base metal, exhibited a greater hardness due to additional dilution by Type 347 metal. At the juncture of the weld metal and base metal a hardness of 240 VPN was obtained in the Type 347 base metal; the hardness in the edge of the weld

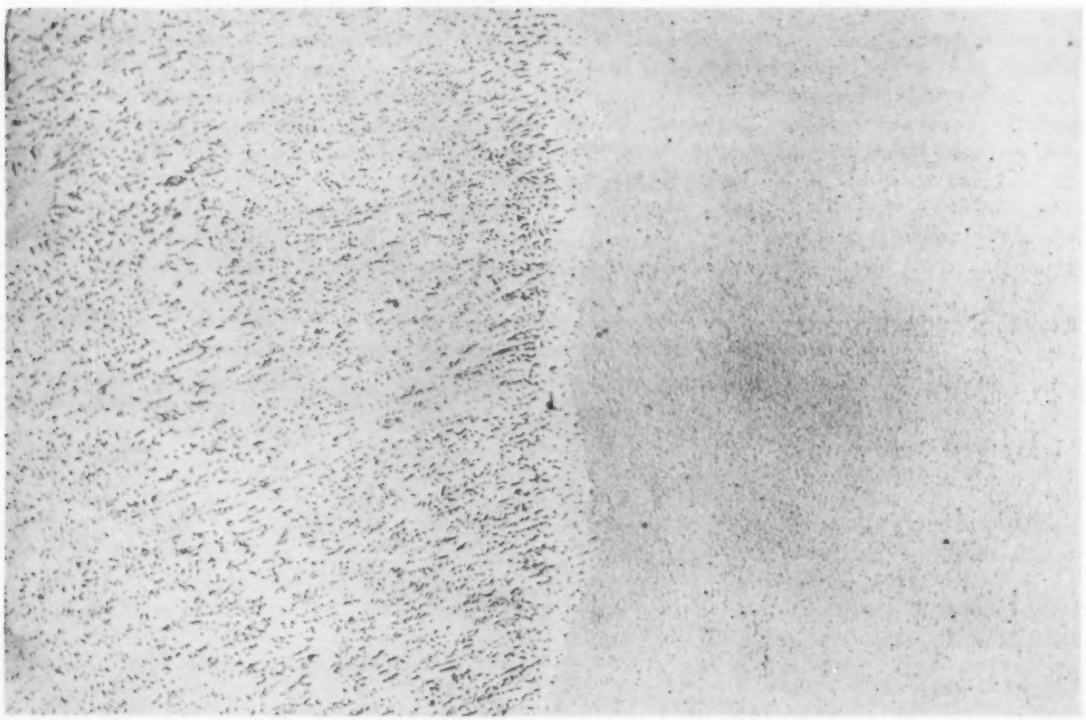


Fig. 21 Photomicrograph of ingot iron—308 L stainless-steel weld juncture. X 100, Method 3

Fig. 22 Photomicrograph of E7016 steel—308 L stainless-steel weld juncture. X 100, Method 4

metal was 272 VPN and rapidly increased to 405 VPN away from the Type 347 base metal; the balance of this diluted weld metal consisting of 347, 308L and ingot iron had an average hardness of 427 VPN, exhibiting a martensitic microstructure.

In Method 4 weld sample (see Fig. 20) a traverse from the Type 308L weld metal through the 308L carbon-steel diluted weld metal to the carbon-steel weld metal gave approximately the same results as Method 3. The diluted zone averaged 375 VPN. A traverse from the 308L weld metal into the carbon-steel base metal indicated a possible increase in the carbon content at the juncture by showing a hardness of 401 VPN in a narrow band adjacent to the base metal. The same effect was noted by a traverse from the 308L carbon-steel diluted layer into the base metal, where one reading of 429 VPN was obtained in the weld metal adjacent to the base metal.

An area was found in one microspecimen where very little penetration of the carbon-steel weld metal into the 308L weld metal occurred. The dilution was so limited that no martensitic structure was observed. The hardness of the carbon-steel weld metal was 206 VPN adjacent to the juncture, whereas the 308L had a hardness of 258 at the same position.

The microscopic examination of specimens made by Methods 2, 3 and 4 revealed no microfissures or unsoundness even in the diluted areas, containing martensite.

Figures 21 and 22 are photomicrographs of the dissimilar weld-metal junctures. Figure 21 exhibits the juncture of the low-hydrogen steel Type 308L stainless steel and the second, Fig. 22, exhibits the juncture between ingot-iron and Type 308L stainless steel.

Conclusions and Recommendations

Stainless-clad steel, with access for welding from the carbon-steel surface only, may be welded satisfactorily by using proper joint design and welding techniques.

1. The use of an ingot-iron insert to eliminate the problem of dilution of the stainless-steel–carbon-steel material, introduces a notch effect into the joint. This notch effect caused failure in practically all of the bend test specimens.

2. In making the transition from stainless-steel weld metal to carbon-steel weld metal the following two procedures could be used:

(*a*) Low-carbon stainless-steel filler metal should overlay the Type 347 weld metal and should be deposited to a height at least $^3/_{16}$ in. above the stainless-steel–carbon-steel interface.

An intermediate layer of ingot-iron filler metal could overlay the low-carbon stainless-steel filler metal. Minimum thickness of this layer should be $^3/_{16}$ in. to act as an effective barrier between the low-carbon stainless-steel weld metal and the carbon-steel weld metal.

(*b*) Elimination of the intermediate ingot-iron weld metal layer is possible if the low-hydrogen weld metal is deposited on an extra-low-carbon 19–9 stainless steel. All possible precautions should be taken to insure minimum dilution at the stainless-steel–carbon-steel juncture and a welding technique designed to produce these results should be followed.

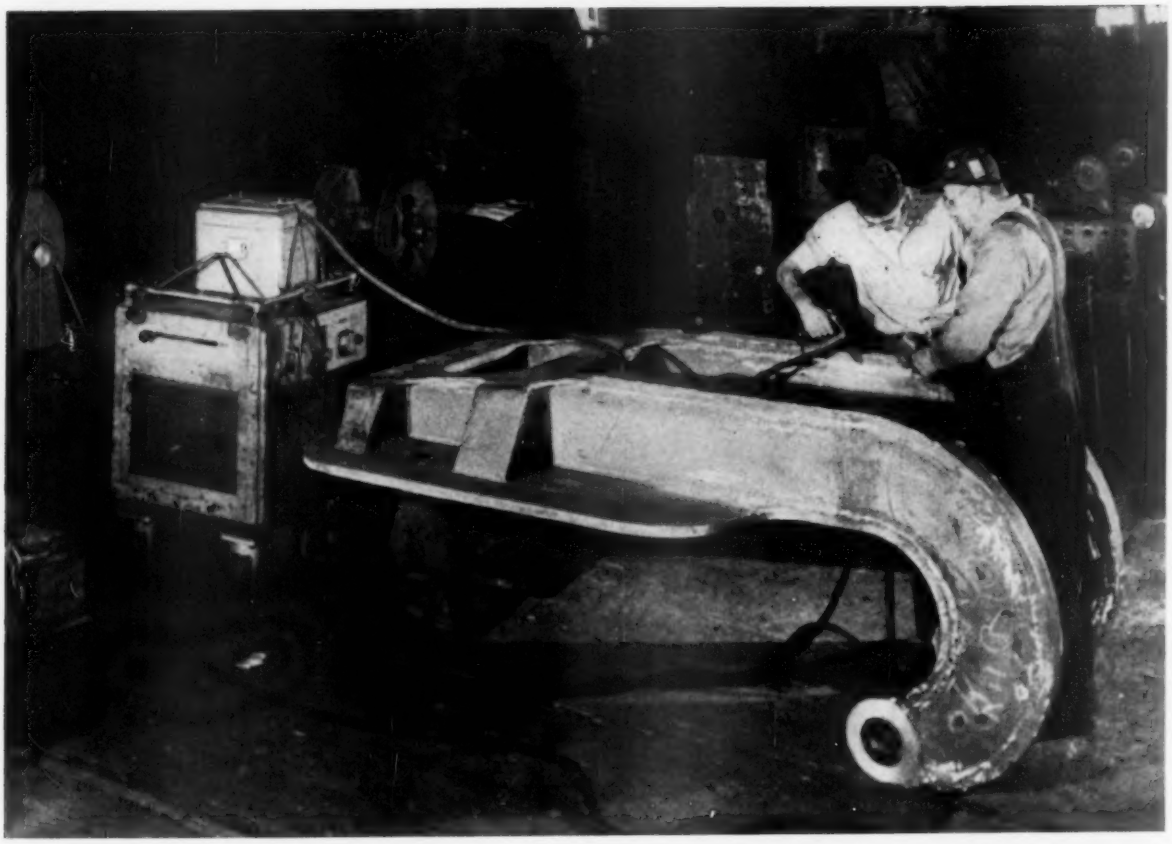
3. Although martensite and other transition phases are present at the carbon-steel–stainless-steel juncture, it must be concluded that these transition products having a low-carbon content do not seriously affect the ductility of the welded joint.

Bibliography

1. Schaeffler, A. L., "Constitution Diagram for Stainless Steel Weld Metal," *Metal Progress*, **56**, 680 and 680-B (November 1949).

2. Risch, T. E., and Dohna, A. E., "Consumable Insert Method of Root Pass Welding," THE WELDING JOURNAL, **33** (7), 670–679 (1954).

3. Thielsch, Helmut, "Stainless Steel Weld Deposits on Mild and Alloy Steels," *Ibid.*, **31** (1), Research Suppl., 37-s to 64-s (1952).



Heavy weldments on road building equipment receive scheduled magnetic-particle inspection to assure desired penetration and freedom from cracks

GREATER ACCEPTANCE OF WELDING THROUGH THE USE OF INSPECTION METHODS

BY JOHN R. HARRER

Special attention is focused on the need for standards when using magnetic particle inspection on weldments which are critical from the standpoint of serviceability, strength and alignment

John R. Harrer, Field Engineer, Magnaflux Corp., Chicago, Ill.

Presented at the 1956 AWS National Fall Meeting, October 8-12, Cleveland, Ohio.

The nondestructive test on which we will focus our attention is magnetic-particle inspection. The weldments with which we will be concerned are critical from the standpoint of serviceability, strength and alignment. This paper points to the basic needs for magnetic-particle inspection, weldments and, for that matter, any other nondestructive test and fabricated part.

What Are the Needs?

Regardless of type, any nondestructive test requires the same basic preparations. It would, therefore, appear that this paper could be more appropriately titled "What Are the Needs?" First, what are the needs or requirements of the weldments? Secondly, what are the requisites of any nondestructive test to assure the quality of that weldment?

Considering these two points, a heavy-equipment manufacturer may say that such a review of all his weldments is an impossible task. Most certainly, an easy way out of this assignment is to disregard a systematic nondestructive testing program and to make believe that there is control of quality by putting out the fires as they occur, but only after they have done their damage.

Today, with the ever increasing demands for strength, alignment and service at a competitive price, those companies that are applying systematic nondestructive testing programs to their everyday production are those companies that are recognized as leaders in their respective fields.

What exactly do we need? The first approach that is always suggested is to set standards. But what are standards? Standards can mean many things. Each, however, must tie in with the other in order for any of them to be successful.

As a start, the most important divisions of a so-called standard are (1) procedure, (2) acceptance and (3) performance in service and records thereof.

Using the magnetic-particle inspection method on welds, standards of procedure are somewhat easy to arrive at. The three most important variables are:

1. Type of magnetizing current.
2. Amount of magnetizing current.
3. Prod spacing.

Some companies have constructed sample blocks of artificially created defects in order to arrive at the correct prod spacing and amperage level for a given penetration. This block is somewhat difficult to construct and, in many cases, it is impossible to artificially create the type of defect that is encountered in normal production.

The most satisfactory approach to this problem has been achieved by slotting from one side a series of cuts $^{1}/_{32}$ of an inch wide and at varying depths in a 1-in. thick plate, approximately 24 in. square (see Fig. 1).

To the bottom of the cut side, a butt strap was welded to cover the slots. Inspection was then performed on the uncut side of the plate. This is not the optimum in arriving at procedural standards, for it cannot apply to all types of welds. To date, however, it has proved to be the best yardstick for determining sensitivity.

Perhaps we can go back to the three variables and expand on each of those. First, we specify the type of magnetizing current. Three types can be used with varying effectiveness: (1) straight a-c; (2) full-wave rectified or generated d-c; (3) half wave rectified a-c.

Straight a-c current provides plenty of pulsation for movement of the particles. However, because its polarity reverses itself 60 times per second, there is no penetration below the surface. A-c current is therefore limited to surface inspection only.

Full-wave rectified current is available in welding generators and in manufactured power packs specially made for magnetic-particle inspection usage. Because it is in effect constant, surge-free, d-c output, the welds must of necessity be ground smooth before using this type of current for magnetizing purposes. This is probably its biggest disadvantage.

The constancy and polarity of the d-c power source does not motivate magnetic particles so that they pulsate or move. This is commonly referred to as "banding of the particles." These magnetic particles are held fast on the weld and also collect heavily in the irregular surfaces of the weld. At best, this power source offers a surface inspection only.

Half Wave Is Best

The half-wave rectified a-c current is always single phase. Its polarity is constant and it provides magnetic penetration into the depths of the welds. In reality, it is a pulsating dc. The surges of current occurring at each cycle motivate the magnetic particles

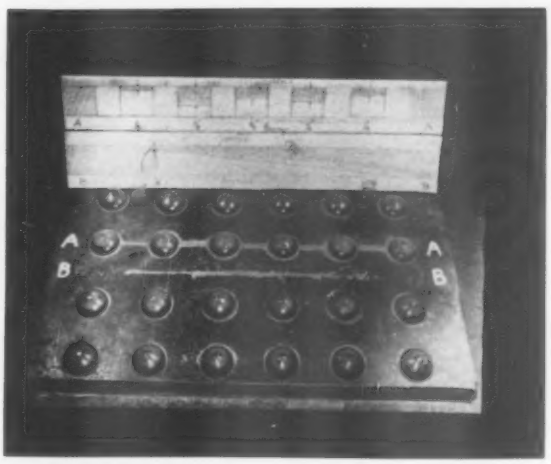


Fig. 1 Simple test block is constructed to gauge current and prod spacing specifications for varied penetration

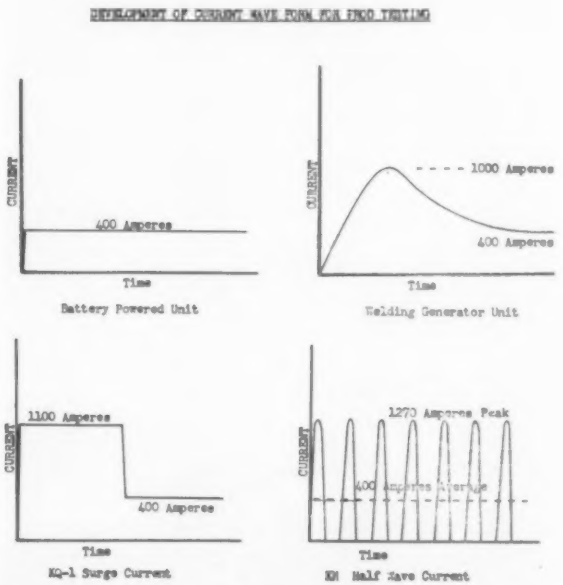


Fig. 2 The half-wave, pulsating d-c current provides for complete powder mobility and deep penetration

which forces them to move and form indications even on very weak magnetic leakages. Even in the valleys of the weld ripple, the particles move and do not become trapped. Excessive trapping could possibly obscure an indication of the weak leakage of a deep subsurface discontinuity. This mobility or movement has often been described as "dancing of the particles." This is the best known type of current for over-all magnetic-particle inspection, both surface and subsurface (see Fig. 2).

Most manufactured equipment expressly made for magnetic-particle inspection of welds has secondary voltages of 10 to 17 v with output ranges from 1000 to 5000 amp. Most weld inspection is performed using between 600 and 2000 amp, depending on plate thickness and also prod spacing. The selection of a unit for secondary voltage and total amperage depends on three main factors: (1) the distance from the machine to the point of inspection; (2) the frequency of inspection; and (3) the danger of arcing or burning the part being inspected. The rating of equipment such as 1000 or 5000 amp is based on a short and intermittent use. A 1000-amp machine will best be operated at 300 amp for nearly continuous output, while a 3000-amp machine will operate at 1250 amp continuously.

A-c or d-c generators without secondary breakers normally operate at substantially higher voltages and can do serious harm to operators or parts because of severe arcing. In addition, only a few welding generators are capable of producing more than 300 amp and still fulfill the duty cycle required for weld inspection without damage to themselves.

Prod spacing can be varied or rigid depending on the preinvestigation of procedural standards. One company uses only two settings on an adjustable double prod, 3 and 6 in. (see Fig. 3). For these two prod spacings the amperage is varied as the thickness of the weld increases. Under no circumstances is it possible to go less than 3 in. with current levels of 500 amp or more. The tremendous flux density between the prods would "band" the particles regardless of the type of current used. For strictly surface inspection, a prod spacing of 18 in. at 600 amp is not uncommon. One typical standard for a 1-in. plate single-V butt weld is 6-in. prod spacing at 1850 amp—half-wave (see Fig. 4). This procedure has been proved to dependably locate lack of penetration at 60 to 80% of the weld thickness on an automatic weld and find root cracks on multiple pass welds.

For procedural standards the above data are all that are necessary to set the wheels in motion.

With little more than several weeks experience under direct supervision, an inspector can be left alone to interpret and evaluate magnetic particle buildups. The foregoing is, however, the simplest and perhaps the smallest part of the three phase standard. The next step is to discuss acceptance standards.

Fig. 3 Prod spacing is varied for added control of sensitivity. For surface inspection only, prod spacings of 20 in. are not uncommon

Fig. 4 For continuous inspection of the same weldments, a predetermined prod spacing is made on a single holder

Accept or Reject?

Generally, it can be safely said that a weld with a crack or lack of penetration is not as strong as one without either. Companies involved in the fabrication of supercritical quality could then set an acceptance standard based on magnetic-particle inspection where any crack or indication is a reject and must be repaired. These cases however, are in the minority. The bulk of the acceptance standards work therefore is less critical. Acceptance or rejection must be based on appearance, size and/or orientation of the magnetic-particle indication (see Fig. 5).

Even with appearance, size and location established, this standard is far from complete. However, with proper scheduling of inspectors, enough of the welders can be watched to protect against serious deficiencies. This is certainly not an ideal situation but, as a chief inspector of a heavy equipment manufacturer stated, "This is far better than anything we have found—before magnetic particle inspection we had no real check at all."

This company and others are not satisfied with the situation and are proceeding with the third phase of the standard; that is, records and field performance tests to further pin down the type of magnetic-particle indication that must be removed and that which is acceptable. An engineering and research group might tackle this problem in the following manner, based on a hypothetical case using a welded "C" frame on a heavy earth mover.

With the use of modern stress analysis tools, brittle lacquers, ceramic coatings and strain gages, accurate qualitative and quantitative stress concentrations can be determined. These stress concentration areas are the ones that must be watched most closely.

These areas are inspected very carefully by magnetic-particle inspection and those frames with known magnetic-particle indications (at this time we certainly cannot call them defects) are placed in field testing or simulated loadings in the laboratory. An important step in this sequence is to transfer the exact shape and size of the indication to a full-scale drawing of the area inspected. This is done by merely placing clear scotch tape over the magnetic-particle indication, slowly peeling it off and pasting it on the drawing. In a sense, this test may be destructive, because these parts may very well fail in the test. However, this leaves little question that this type of indication must be found and repaired and steps taken to prevent its recurrence. After the test is run, a reinspection and scotch tape transfer is made and compared with that on the original print. Any progress of the magnetic-particle indication can be noted and appropriate action taken (see Fig. 6). At this time, design and quality control men can take

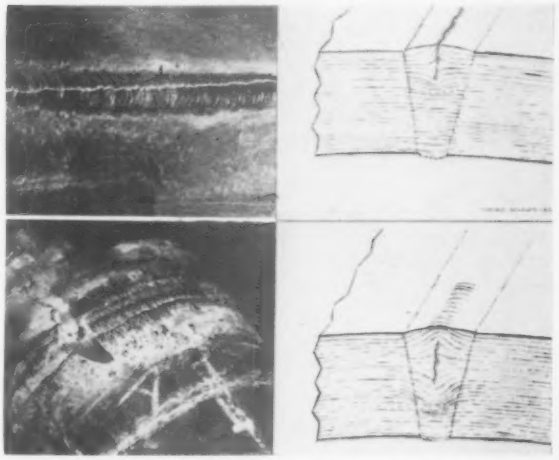


Fig. 5 Surface and subsurface magnetic-particle indications are easily interpreted by the height and width of the powder buildups

their first steps of evaluating the type of indications that will be tolerated in these areas and conversely those which cannot be permitted.

For the heavy-machinery manufacturer who may have as many as 4000 individual weldments, this approach may seem an impossible task. However, first we can eliminate many parts, and secondly with great similarity in many parts, a single investigation may suffice. At least it may point out the direction of subsequent investigations to cover other similar groups of parts. Thirdly, we can rely on the records of field failures. By maintaining accurate records of the fail-

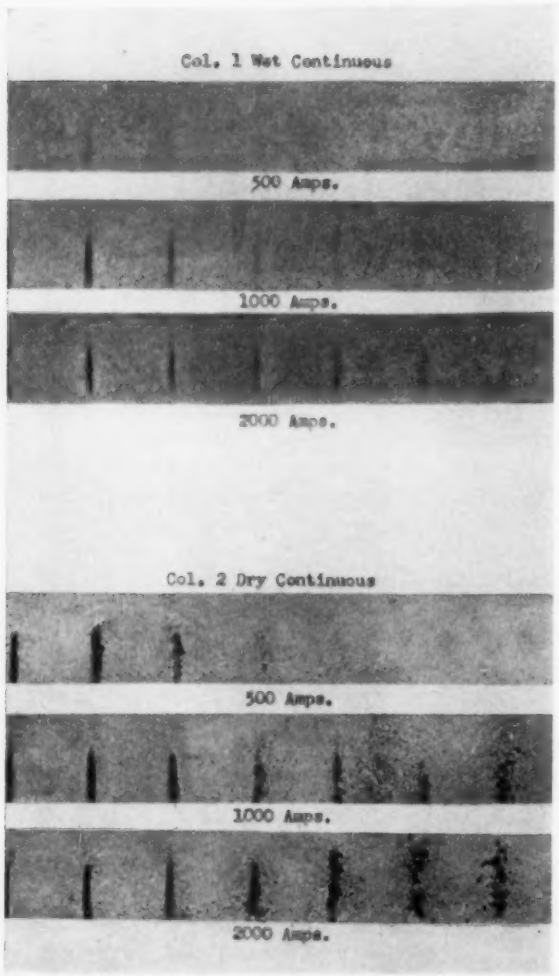


Fig. 6 Magnetic-particle indications vary sufficiently to easily evaluate the type, or to note defect progression during field or laboratory tests

ures and their apparent causes, the line can be drawn tight enough to point to the eventual acceptance standard.

A lot of argument can be given about the economics involved here, and the momentous job that we try to typify. However, until a nondestructive test is devised that will answer all the facets, magnetic-particle inspection does provide quick and easy assurance of quality. To illustrate this approach a noted diesel engine manufacturer spent 15 years testing, watching and recording before arriving at a magnetic-particle inspection acceptance standard that they knew was right. During this time, however, they have also built up a reputation in their field that this particular part, and we refer to a crankshaft, was the most dependable of any in its field. Modern stress-analysis tools speed this process and materially reduce cost.

Which Nondestructive Test?

Most production and engineering departments concur that what is actually needed is a nondestructive test that will tell when a weld is sufficiently acceptable to do the job expected of it. With a full understanding, however, of the demands to be placed on the welds and with a procedure and acceptance standard, illustrated by the use of magnetic-particle inspection, it is possible today to determine the soundness of the welds. It has been confirmed time and time again that magnetic-particle inspection will show when there is really a bad weld. The inverse is also true. One can expect good performance from materials and weldments free of detrimental magnetic-particle indications.

Many factors contribute to acceptance of weldments in heavy industry. In addition to reductions in cost, rigidity and alignment are important assets of the weldment. Where strength is secondary, and rigidity and alignment are the most important factors, maximum penetration of welds is necessary for satisfactory results in further fabrication and actual operation.

Several manufacturers of road-building equipment have experienced excellent results with magnetic-particle inspection. In fact, some state that it is not used for the detection of cracks at all, but to reveal the lack of desired penetration.

A manufacturer had sufficient experience on certain frames to know what penetration was more than adequate to maintain alignment. What was needed here was a nondestructive test to rapidly point out areas of less than the 80% penetration. A specially prepared sample block, similar to the one described earlier, was made to simulate the penetration depths in 1-in. plate. Subsequent trial and experimentation with magnetic particle inspection revealed the exact prod spacing and amount of half-wave current needed to produce indications of 65, 40 and 20% penetration. This information was in turn written up by the quality control analysts. Each inspector could refer not only to the procedure but, by having standards on that specific weld, he knows that any indication means less penetration than required for a weld that will perform satisfactorily in service.

Conclusions

In conclusion, the task of gaining greater acceptance for welding need not be monumental. It does require knowledge of the service life expected, what is or is not acceptable and a simple inspection procedure will do the job. It is sincerely hoped that this discussion will be helpful to many companies already using magnetic particle inspection to organize a program directed to the development of standards as, the author is pleased to report, so many are already doing.

WELDING ALL-ALUMINUM SUPERSTRUCTURES FOR U. S. NAVY DESTROYERS

An outstanding demonstration of versatility in the welding of aluminum by the gas-shielded metal-arc process

BY RALPH BRADWAY

AND C. G. SERROI

Fig. 1 U. S. Navy destroyer in wet dock, N. Y. Shipbuilding Corp., Camden, N. J.

With more than 50 years of development and diversification in the heavy industry field, New York Shipbuilding Corp., Camden, N. J., is unique both in the range of its production capacity and in the distinctive results of many of its production performances.

The design and construction of the hulls, machinery and gun turrets of naval vessels—as well as a large volume of work other than ships—have provided experience in the welded construction of a wide range of medium and alloy steels—including nonferrous metals such as aluminum.

A spectacular current achievement with aluminum by this company is the construction of four destroyer escorts for the U. S. Navy. These ships are designed for all-aluminum superstructures, making for lighter weight and greater escort speeds—another "first" in the welded fabrication of heavy structural aluminum in the marine field.

To do the job, New York Ship is using the inert-gas-shielded metal-arc process.

Major components of the superstructure—mast, stacks, deckhouse, ready service rooms, etc.—are fabricated in sections at the shop and then assembled on the ship where additional welding completes the job. This provides for as much downhand welding as possible in the shop, speeding production, and gives the operators plenty of room and maneuverability for positioning the workpieces.

The subassembly of the deckhouse requires welded butt seams 20 ft long and more, along with numerous fillets on structural members. Much of the welding on this component is done in the shop prior to final assembly on the ship. Fast deposition rates of the process minimize exposure of the aluminum to heat and eliminates distortion.

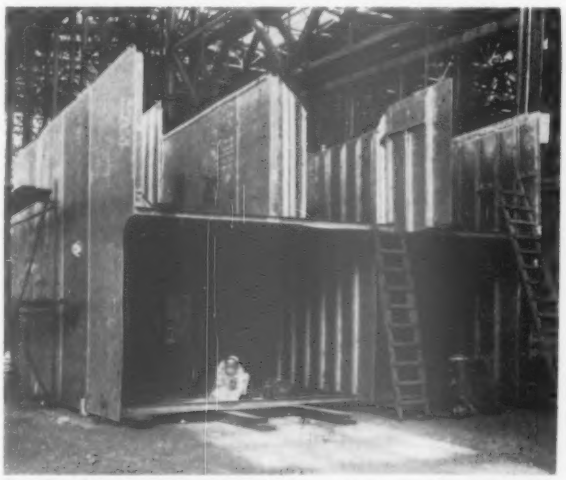


Fig. 2 Subassembly of deckhouse shown upside down with operator depositing a fillet along a structural member with gas-shielded metal-arc process

Ralph Bradway is Welding Engineer, New York Shipbuilding Corp., Camden, N. Y., and **C. G. Serroi** is Process Representative, Air Reduction Sales Co., Philadelphia District.

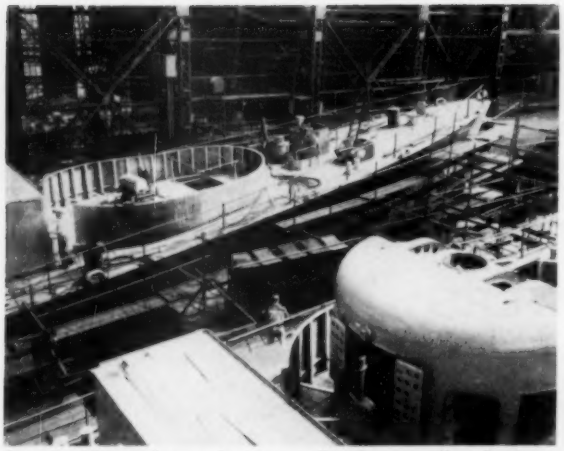


Fig. 3 View of two destroyers "in the ways"; aluminum gun shield has just been installed on destroyer in background

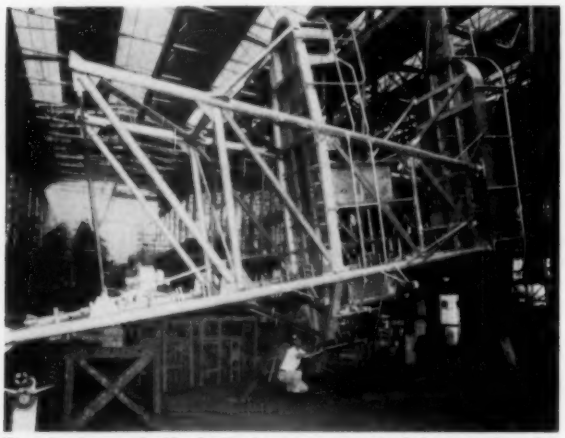


Fig. 4 Lower half of all-aluminum mast is fabricated in the shop along with two other mast sections

Another prefabricated section for the superstructure of a destroyer is the mast. Fabricated in three separate parts in the shop, the mast involves the use of aluminum thicknesses from $^{5}/_{16}$ to $^{1}/_{2}$ in. requiring the manual versatility of the gas-shielded metal-arc process for all-position welding.

Welding on the ship in particular calls into play the all-position versatility of this process, making possible fast, efficient construction of the superstructure as components are assembled for the final welds.

Practically every type of weld in the process manual is made on a structural job of this type—circular fillets, straight runs, long butts, short start-and-stop welds.

Fig. 5 Long butt seam in deck flooring of a destroyer—another example of weld fabrication on this pioneering project

Fig. 6 Two destroyers in wet dock nearing completion

tight welding in close quarters—all on aluminum material ranging from $^{1}/_{4}$ to $^{1}/_{2}$ in. thick, and from every conceivable position.

AUTOMATIC WELDING PROCESSES BOOST PRODUCTION OF HOT-WATER HEATERS

Two carefully selected automatic welding processes teamed with specially designed fixtures enabled the Rheem Manufacturing Co., South Gate, Calif., to boost production of glass-lined hot-water heaters and decrease labor costs.

Selection of the two automatic processes came after a company study of former production methods. The goal of the study was to find methods of speeding production of cope with an ever-increasing demand for the heaters. In its study, the company considered the time and cost involved in handling, welding, and finishing. Mechanized operations were desired, wherever possible, to step up production and insure quality work.

Automatic argon-shielded metal-arc welding replaced the manual arc welding of flues to bottoms of heaters. It was selected over other automatic processes because of the small diameters involved, fit-up problems, and the necessity of holding the arc in close proximity of the joint. A gas-shielded metal-arc welding outfit mounted over a rotating fixture completes this welding operation in less than 30 sec including loading time. This process produces smooth welds which eliminate the need for cleaning and grinding, reduces arc time and percentage of rejects, and does not require a specially-skilled operator.

Based on a story by the Linde Air Products Co., New York, N. Y.

Speeds exceeding 100 ipm are attained in the automatic submerged-arc welding of longitudinal seams of steel tank shells from sheets of 10 and 14 ga. thicknesses. Welds are smooth and require little finishing.

Two men, using a submerged-arc welding head at-

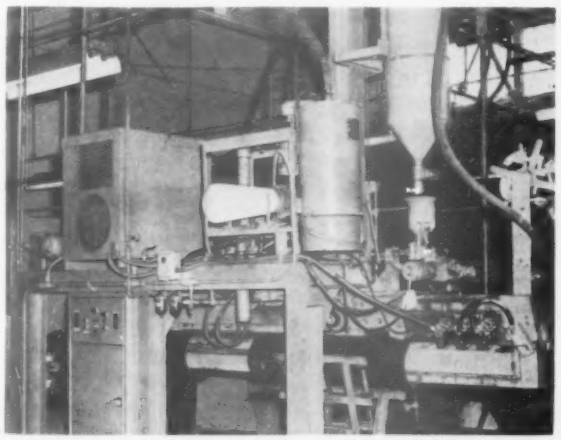


Fig. 2 Two rolled sheets of steel are in position for the automatic submerged-arc welding of longitudinal seams of tank shells. Flat sheets are guided by an operator into a true circle roll at the rear of a continuous tank mill. The shells, pushed into the welder by a pneumatic ram, are moved to the welding head by means of cams

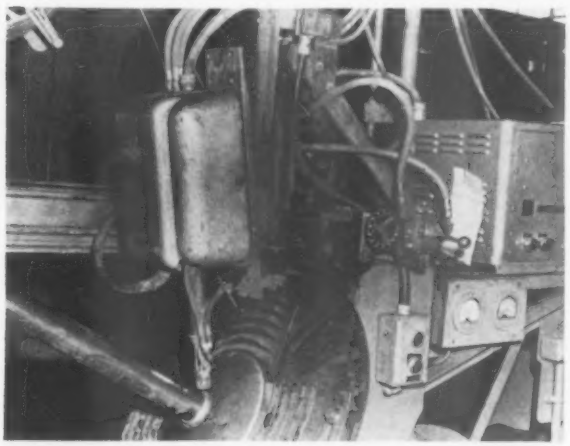


Fig. 1 A special rotating fixture is used for the automatic gas-shielded metal-arc welding of flues to bottoms. Loading includes the placing of the bottom in slots of a turntable and the forcing of the flue against a spring-loaded insert acting as a backup for the weld. Centered and off-centered bottoms are welded easily

Fig. 3 After the seam is butted tightly together, the shell is moved forward over a water-cooled backup shoe by separately driven power rolls. A welding operator pushes a button to weld a longitudinal seam of a shell at a speed exceeding 100 ipm. High-quality weld beads need little finishing. Limit switches control the sequence of the operation

tached to a special fixture now complete a job which previously required four men using a double loading fixture. One man pushes flat sheets of steel into a true circle roll that forms the shell and the other controls the welding operation. Two zinc blocks mounted on the forward side of the fixture help to reduce magnetic fields by providing additional grounding of the shell as it travels under the welding head. Previously, one man was required for rolling, another for end alignment, and two others for loading and welding.

ALUMINUM COVERS PROTECT HIGH-TENSION BUS BARS

High-speed mechanized gas-shielded tungsten-arc welding has filled the need for uniform, warp-free welds in the fabrication of aluminum covers for high-tension bus bars at the Chicago plant of the Delta-Star Electric Division of H. K. Porter Co.

These isolated-phase bus bars are required between generators and transformers of power stations. Dust-tight covers for them are fabricated from pre-rolled aluminum tubes, 19 to 36 in. in diam and up to 8 ft in length. They are made from $^1/_8$ in. thick, 1100-H12 or 1100-H4 aluminum alloy sheet.

The rapid welding rate, 24 to 36 ipm, minimizes warpage in the aluminum tube. Inert argon gas is fed through the torch to prevent contamination of the weld zone by the atmosphere. No filler metal is needed in the operation—the cover is welded by fusing the aluminum along the longitudinal joint.

To insure complete weld penetration without burn-through, a stainless steel backup bar is positioned under the edges of the joint. Tabs at each end of the joint allow the automatic welding to proceed beyond the ends of the cylinder.

Sufficient weld ductility is required, since circumferential grooves must cross the weld near the ends of the cylinder. These grooves are designed to hold 0.051-in. thick flat rings made from 18-8, or Type 302 or 304 stainless steel.

The versatile tungsten-arc apparatus is also used to weld the stainless steel rings. Although these welds are only a few inches long, the high speed of automatic welding actually saves time—and money—in the long run.

Based on a story by the Linde Air Products Co., New York, N. Y.

Fig. 1 Completing the longitudinal weld, a tungsten-arc torch moves along a track beam above the aluminum tube. The prerolled tube is supported on a cradle and is clamped between copper bars

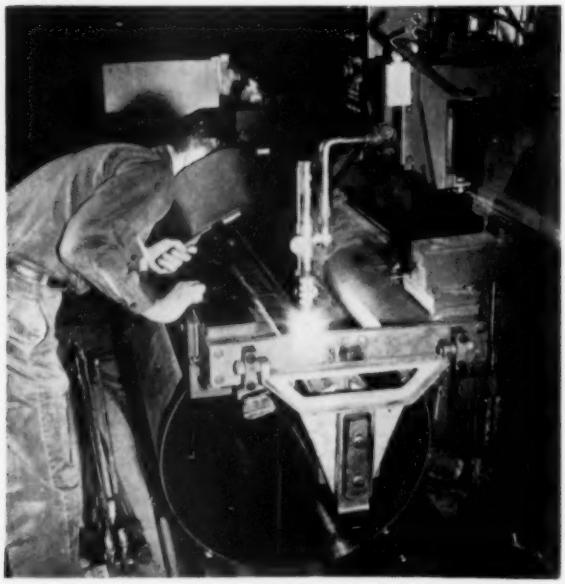


Fig. 2 Various sizes of aluminum covers for high-tension bus bars are shown above

MODERN WELDING PROCEDURES SPEED COMPLETION OF 290-FT OIL BARGE

BY DONALD HASTINGS

One of the largest all-welded steel, nonpropelled barges ever to slide down the ways is the 290-ft *Amorco*, built in the yards of Pacific Coast Engineering Co., Alameda, Calif. for the Tide Water Associated Oil Co. Designed for coastwise transport of bulk petroleum products, it has a capacity of 270,000 cu ft, or 48,100 bl. The beam is 50 ft; depth, 20 ft; draft, 15 ft 9 in. It is constructed to class +Al specifications of the American Bureau of Shipping and in accordance with the latest regulations of the U. S. Coast Guard.

The barge, as shown in accompanying illustrations, is of the flush deck type, with raised sheer at both ends. The bow is of special design for operation in rough coastal waters, and two antiyawing skegs are fitted at the stern to facilitate on-course stability. The deckhouse at the stern is 14 ft long and 30 ft wide, housing pumping units and headquarters for the operator. In the event heavy oils are being carried, steam coils have been installed in the hold to heat the cargo for easy pumping ashore.

The use of welded steel-plate construction throughout greatly speeded assembly operations. One of the illustrations herewith gives an idea of the honeycomb of plates and I-beams making up the internal structure. Deck plates were butt welded on both sides. One side was manually welded and the other made use of semiautomatic welding. The latter is, of course, the submerged-arc principle, with the welding guns being mounted on suitable carriages and guided along the joint by the operator. All out-of-position welds were made manually with $^{5}/_{32}$- and $^{3}/_{16}$-in. mild-steel coated electrode.

Much of the welding of plate subassemblies was handled in the Paceco shops. Considerably higher welding speeds can be realized where the work can be positioned flat. This minimizes the amount of out-of-position welds which must be made at the erection site. A further contribution to faster welding in the shop has been the introduction of electrodes with iron powder in their coating, powered by alternating current. Travel speeds 15 to 25% higher are possible with these electrodes, and, in addition, cleaning time is reduced by virtue of elimination of spatter and easy slag removal.

Because of the higher speeds possible with a-c welding in the flat position, Paceco has installed a battery of combination welding machines which supply alternating current through a transformer, or direct current by means of a rectifier package. They may be operated on either single-phase or three-phase power supply and have full variable current control, as well as an arc booster for quick starting. Arc characteristic

Donald Hastings is Welding Engineer; Lincoln Electric Co., Emeryville, Calif.

Fig. 1 Launching of this 290-ft all-welded steel oil barge was a gala event at the yards of Pacific Coast Engineering Co., a portion of which is shown in the background

Fig. 2 Construction view of the nonpropelled barge shows the honeycomb of welded steel plate and structurals comprising the inner framing. Capacity is 48,100 bl

may also be varied to suit the job. Where both a-c and d-c welding are being done, these combination units are ideal for minimizing downtime to take care of an equipment change.

The same a-c, d-c units are being installed in the yards for outside work, where, for the past 20 years, 99% of all welding has been done with d-c motor generators. Savings of about $600 per year per machine are envisioned, through reduced power, maintenance, labor and overhead costs.

For discharging cargo, the barge is fitted with two 12-in. four-stage, vertical centrifugal, stripping pumps, drive through a top-mounted, right-angle gear by 210-hp, 6-cylinder diesel engines. The electrical installation comprises a tray of 32-v batteries for starting the pumping engines and for lighting. A diesel-generator set in the deckhouse charges the batteries.

At the bow is a double-drum wire, rope windlass, each drum having capacity for 105 fathoms of $1^1/_4$-in. wire rope which is attached to a 1500-lb anchor secured on a billboard. Two 5-ton cargo hose masts are provided midship for handling the cargo hose, each being fitted with two 5-ton hand hoists, one for the topping lift and one for the cargo hook.

The barge was completed and launched in approximately six months from the date the keel was laid. Calibration and operating trials preceded delivery to the customer.

ROTARY DRUM STORES PRE-MIXED FLUX FOR BRAZING OPERATION

The Westfield Manufacturing Co., manufacturer of Columbia bicycles, silver brazes most of the joints in its bicycle frames. Formerly, each brazing operator mixed his own flux, with the result that the flux varied in consistency from one brazing station to the next.

Uniform flux contributes to good brazing and is good economics as well. Thin flux runs off easily, which can prevent the brazing alloy from wetting uniformly, and exposes the base metal to direct heat, which can complicate clean-up operations because of the scaling or discoloration produced by overheating. Thick flux is hard to apply evenly and frequently is wasteful.

To assure a flux consistency that would be correct and economical, and to save the operators' time as well, this manufacturer centralized the operation and now mixes enough flux in a single batch to supply several shifts. This centralized method permits the use of 60-lb flux containers and takes advantage of the savings from purchasing the flux in bulk quantities. The flux is mixed and stored in the rotary drum shown in Fig. 1, from which operators refill their flux containers whenever needed. Since the drum is completely closed, the properties of the flux remain uniform until it is used up.

The drum is rotated at about 40 rpm by a V-belt drive to provide a continuous mixing action. A lever-operated coupling on the drum axle disconnects the drum from the drive, so an operator can stop the drum to pour out flux without shutting off the motor. The flux is delivered through a 2-in. diam bushing capped with a hex-head nut, to which a handle was welded for greater convenience in opening and closing. Short longitudinal vanes welded to the inside walls of the drum provide enough agitation to maintain constant mixing of the flux as the drum rotates. The drum body was fabricated from mild steel sheet and the seams welded.

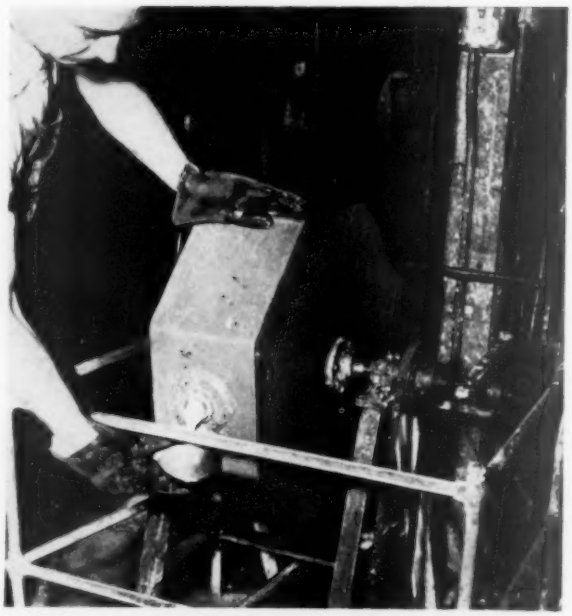


Fig. 1 Flux drum holds enough premixed flux to last for several shifts; premixing assures uniform flux for entire shop, saves time and cuts waste

Based on a story by Handy & Harman, New York, N. Y.

FAST FABRICATION OF FIRE BOMBS

BY LARRY KUNKLER

Evans Reamer and Machine Co., New Lexington, Ohio, an affiliate of Lempco Products Inc., of Cleveland, fabricates 750-lb aluminum fire bombs for the U. S. Government in a fast efficient manner.

This company has developed a production pattern around 20 welding stations which make use of both gas-shielded tungsten-arc and gas-shielded metal-arc processes (see Fig. 1.) These processes are applied on a manual, machine and fully automatic basis, depending on the joint.

The bomb is 13 ft long and 18 in. in diameter. It is made in three sections: a nose, center shell and tail. Tooled for a production rate of 3000 bombs a month, the manufacturer achieves unusually fast welding speeds, particularly on the center sections of the bombs.

The center section requires two circumferential welds which are made simultaneously with two automatic metal-arc welding heads mounted at each end of a special installation (see Fig. 2). These girth seams are completed at 106 ipm with 271 ipm filler wire feed.

At the start of the production cycle, straight lengths of aluminum are put in a flat bend machine and rolled into rings that serve as structural components, four for each bomb, one for the nose, two for the center and one for the tail. These are bevel cut with a saw for a single-Vee butt weld made at two stations with manual consumable-electrode units.

Larry Kunkler is process representative, Air Reduction Sales Co., Pittsburgh District.

Fig. 2 Automatic gas-shielded metal-arc welding heads simultaneously welding two girth seams 60 in. in circumference on center section of aluminum fire bomb; this automatic operation achieves welding speed of 106 ipm

Fig. 1 View of flow of bomb sections from station to station

Fig. 3 Manual tungsten-arc welding is used on filler cap and arming wire tube on the bombs; five production stations for manual welding are used on this project

The sheet for the skin of the nose and tail sections is sheared and rolled, cone shape, for longitudinal butt welds. Two semiautomatic tungsten-arc installations are used to make these welds. For example, on the tail section, a machine tungsten-arc holder, mounted on a carrying machine, moves along the seam and lays aluminum wire into the joint. Both nose and tail sections also require circumferential welds and two semiautomatic tungsten-arc installations are used for them.

Five production stations are devoted to tungsten-arc manual welding the bomb filler cap and arming wire tube. (see Fig. 3.)

IRON-POWDER ELECTRODE EFFECTIVELY USED IN FABRICATING TURNPIKE EXPANSION JOINTS

BY ROBERT HALL

Bridges, built as part of the interstate highway system, require, in many cases, steel expansion joints having a section similar to that shown in the accompanying sketch, Fig. 1. Ordinary rolled sections are not applicable because height from end to end varies, since the roadway surface slants from high point at the center to a lower level at each side. Fort Pitt Bridge Works, Canonsburg, Pa., fabricates them from flat steel plates. In fabrication, the top plate, which is sloped, is welded to two upright plates whose top edge is cut at an angle matching the slope. In effect, this provides a channel section formed by two T-sections, but, initially, the tops of the two T's are formed by a single plate. Later, two other flat plates are added, one at each side, as shown in Fig. 1.

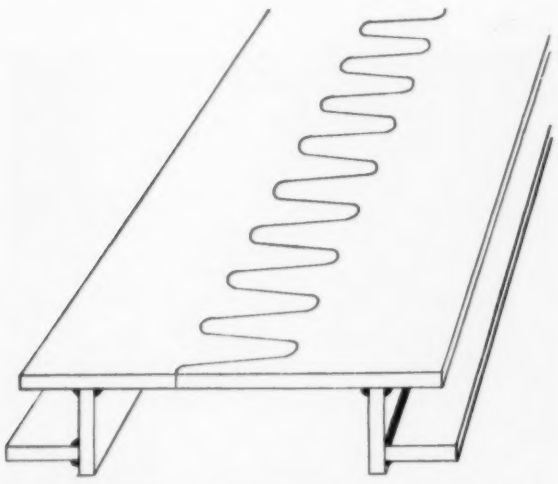


Fig. 1 Perspective sketch of a short section of the expansion joint for Ohio Turnpike bridge application that is being fabricated with iron-powder type electrodes by Fort Pitt Iron Works

Finally, after welding is completed, the top plate is oxygen cut into two parts along a sinuous line to form interlocking fingers (see Fig. 2). When set into the roadway, the two halves are so placed that, in hot weather, the fingers nearly touch. As contraction occurs in cold weather, the fingers are drawn apart slightly, yet still mesh so that only narrow gaps result and tires roll over so smoothly that the joint is scarcely noticed by car occupants.

Fabrication of the assembly is done by hand arc welding, using a E-6024 iron-powder type electrode. Welding is done about twice as fast as with conventional covered electrodes. Welds are exceptionally clean and smooth.

Robert Hall is Welding Engineer, The Lincoln Electric Co., Pittsburgh, Pa.

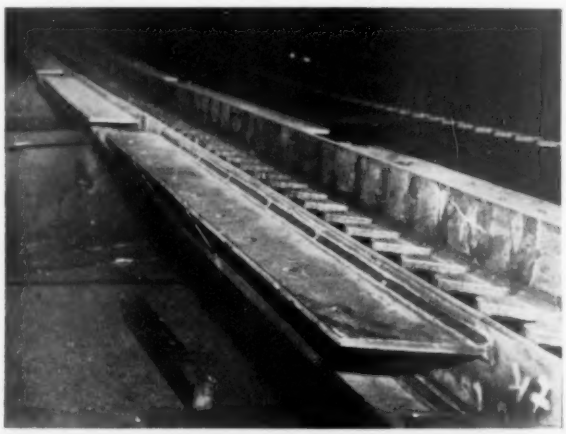
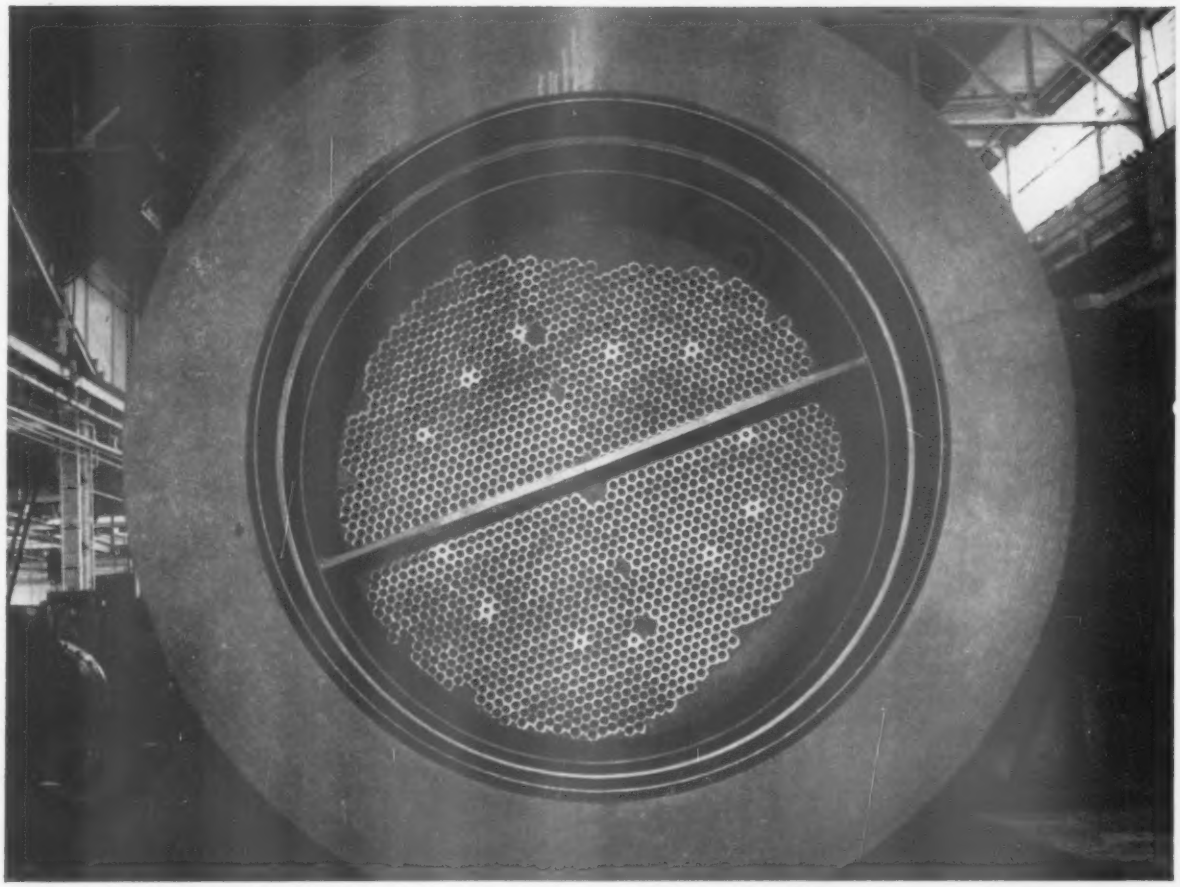


Fig. 2 Set of expansion joint halves after they have been fabricated and have been cut apart along a sinuous line to form the "teeth" of the joint. Note smooth, clean appearance of welds made with iron-powder type electrodes



First all-welded heater. *First step:* strong, sound welds between copper-nickel tube ends and steel tube sheet made with "140" Monel electrode. *Second:* fabrication of a welded shell with stainless steel back-up strips . . . to protect tube bundle during welding. *Third:* welding torus ring seal at the heater head . . . to eliminate gasketed joint and possible leakage.

How Lummus welds copper-nickel tubes to thick steel sheets in high-pressure feedwater heater with

"140" Monel electrode to get leak-proof joints

They call the round metal forging holding these tube ends a tube *"sheet"*—but it is nearly a foot thick! Welding tubes to this sheet so the joint will withstand high temperatures and pressures could be a nightmare for a weldor.

But it doesn't have to be. The Lummus Company has proved this in welding both Monel* nickel-copper alloy and copper-nickel tubes to thick steel tube sheets. They get leak-proof joints by welding with "140" Monel* electrode.

Now in the first *all*-welded feedwater heater Lummus again calls on this electrode. This unit operates under pressure as high as 3,600 psi . . . uses inlet steam as hot as 790°F. Its tube sheet is steel; tubing, copper-nickel.

"140" Monel electrode produced *corrosion-resisting* joints that prevent the scaling associated with high temperatures. Because of the high nickel content of the electrode, welds are *strong* and *sound*.

Lummus experience indicates that welds made with "140" Monel electrode will retain these properties for tens of thousands of hours.

For high pressure in feedwater heaters . . . when you weld Monel alloy or copper-nickel tubing to steel . . . use "140" Monel electrode.

With other welding processes and alloy combinations, *other* Inco Welding products give you the same superior results. One booklet . . . "Inco Welding Products"... describes them all. Gives recommended applications . . . specifications . . . other useful information. Write for a copy . . . now.

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.
*Registered trademark

INCO TRADE MARK

Welding Products
Electrodes • Wires • Fluxes

MECHANIZED OXYGEN CUTTING CONTRIBUTES TO ACCELERATED PRODUCTION OF TURBINE GENERATORS

BY J. F. BUERKEL

Fig. 1 Oxygen cutting machine cuts and bevels circular piece with two torches—one to preheat, one to flame cut; twenty-ton capacity rotary table revolves circular part as beveling is performed for greater control over angle

Rapidly increasing consumption of kilowatt hours in the United States has been focusing a great deal of attention on the production methods used to manufacture power generating equipment.

A good example of one of the many ways General Electric is solving this problem can be found at the Welded Products Section of the Medium Steam Turbine Generator and Gear Department, Lynn, Mass. Here, one of the country's largest installations of motorized torch-cutting equipment is turning out various steel shapes which go into the fabricated sections of turbine-generators and marine gears manufactured by this department.

Multiple production of steel shapes is accomplished by a battery of pantograph-type shape-cutting machines all equipped with motorized torch holders.

These machines are installed in a row on one side of the bay, permitting passage on the other side of an overhead magnetic crane, a safe and fast way of handling the hundreds of shape-cut parts which make up the turbine-generators.

J. F. Buerkel is Technical Representative, Air Reduction Sales Co., Boston District.

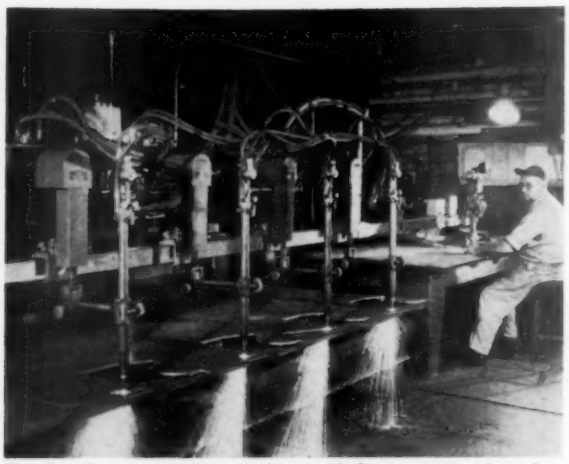


Fig. 2 Oxygen cutting machine with four motorized torches mounted on special racks that allow torches to come out to edge of wider plate; speed, 19 ipm

Within the broad production scope of this oxygen-cutting operation are a number of special techniques and practices which reflect ingenuity and resourcefulness, each contributing in a small but significant way

Fig. 3 Mechanized oxygen cutting of web plate for stator frame which will go into a 44,000-kw generator; operator is starting cut for circular pattern

Fig. 4 Magnetic crane removes circular piece from web plate

to the over-all effectiveness of the manufacturer's power generation manufacturing program.

On one pantograph-type oxygen cutting machine which is used with four motorized torches, special racks on which the torches are mounted permit better utilization of the plate, resulting in less scrap. These racks are three times longer than the standard racks, permitting the torches to come out to the edge of a wider plate.

Fig. 5 Stator web plate showing pattern cuts

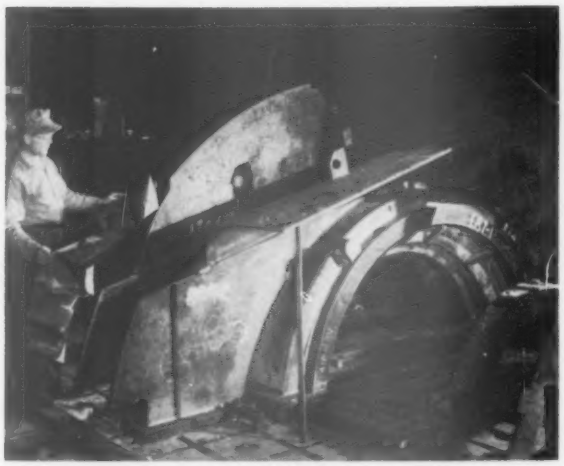


Fig. 6 Exhaust casing being built for 44,000-kw turbine; all parts are oxygen cut from heavy plate

Another innovation at G.E. is the use of a machine for radial cutting and beveling operations. Two torches are installed on the operating bar of the cutting machine, one to preheat, one to oxygen-cut. Built into the cutting table is a 20-ton capacity rotary table with controls for variable speeds. This special device is often used for beveling circular pieces. It is found more efficient, when cutting a bevel in a circular piece, to revolve the part rather than the torch because there is greater control over the required angle.

The rotary table also enables G.E. to cut circular pieces beyond the range of the pantograph shape-cutter, thereby extending the scope of the cutting machine. A circle 21 ft in diameter can be cut with this setup.

Another feature of this installation is the use of motorized torch holders for raising and lowering of torches by remote control. Torches can be raised and lowered $4^1/_2$ in. at a speed of approximately 10 ipm along their centerline of axis. This provides for vertical torch movement without disturbing the angular setting. Numerous angular positions are thus easily achieved with the motorized torch holder.

Some of the steps in the preparation, handling and assembling of the parts are shown in Figs. 1 through 7.

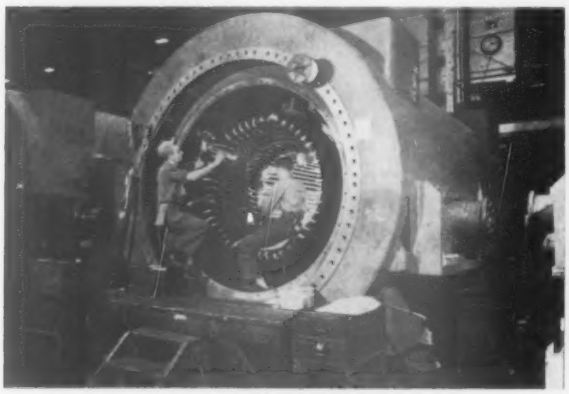


Fig. 7 Winding of generator stator frame

CARRIER ELEVATOR IS LARGEST ALL-WELDED ALUMINUM STRUCTURE IN USA

The recently-christened attack carrier U.S.S. *Ranger* will put to sea with more aluminum aboard than any of the world's fighting ships.

When finally fitted out by Newport News Shipbuilding and Dry Dock Co., the mighty vessel will take advantage of more than 2,000,000 lb of the light metal. The new *Forrestal*-class carrier also features the first all-aluminum deck-edge elevator to be installed aboard the 59,900-ton vessels.

The huge welded structure, largest ever built of aluminum in the United States, measures 52 x 62 ft. It boosts the *Ranger's* use of aluminum by 114 tons over that of her sister ships in the first class ever designed to carry airborne atomic Naval power.

The elevator, installed to shuttle jet planes between the hangar and flight decks, is fabricated entirely of aluminum plate. It saves an estimated 34 tons over a similar structure of high-tensile steel.

Location of the elevator is the forward section of an angled or canted deck, adopted for *Forrestal*-type carriers after exhaustive testing. Where planes formerly landed straight in along the flight deck, on the *Ranger* they will set down on a deck area angled 10.5 degrees from the starboard quarter of the ship's stern.

Extending well past the *Ranger's* control "island," the angled section creates both an exceptionally wide deck and a port side overhang. Selection of aluminum to construct the elevator needed at the forward end of the canted deck eliminated the hazard of excess weight affecting the ship's trim.

Structural members for the vital elevator were either cold formed or cut to shape from aluminum plate ranging up to 2 in. in thickness (see Figs. 1 and 2). The hundreds of pieces required in the plate girder construction were welded by the inert-gas-shielded metal-arc method to fabricate the elevator in two sections. Sections were then lowered into position aboard the *Ranger* and joined by welding, completing an installation large enough to hold two suburban lots with homes and landscaping.

The new *Ranger*, jet-plane equipped and nearly five city blocks long, has an illustrious predecessor. In 1933, the first ship designed from the keel up as an aircraft carrier also was built by Newport News Shipbuilding and Dry Dock Co. She was the first *Ranger*, a 14,500-ton ship that performed illustriously in the Battle of the Atlantic during World War II.

Fig. 1 All-aluminum, all-welded elevator aboard U.S.S *Ranger* is nearly twice as large as Navy's first aluminum elevator aboard U.S.S. *Shangri-la*. Plate girder construction was used, and hundreds of members were cold formed or cut to shape from aluminum plate. Plate thickness ranged from $^1/_4$ to 2 in.

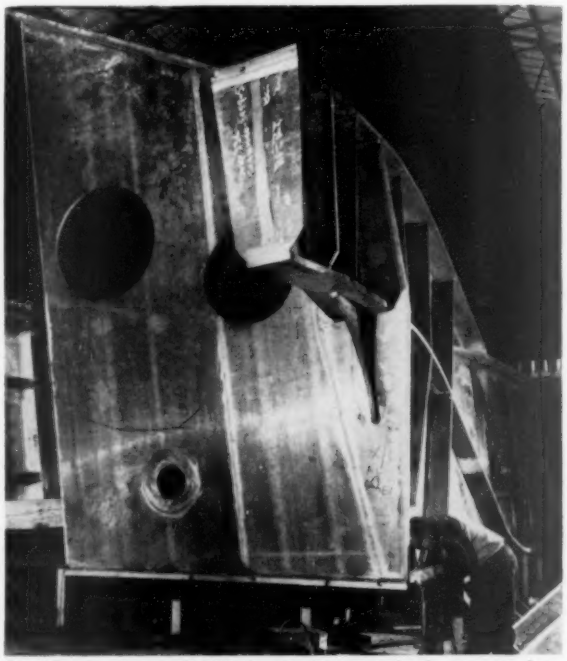


Fig. 2 Inert-gas-shielded metal-arc method was used to fabricate elevator, largest all-welded aluminum structure built in the United States. Aluminum plates up to 2 in. thick were used to make this inboard supporting member

Based on a story by Aluminum Company of America, Pittsburgh, Pa.

WORLD'S HEAVIEST UNIT OF ATOMIC POWER EQUIPMENT BUILT FOR SHIPPINGPORT

The heaviest unit of atomic power equipment in the world, a 235-ton reactor vessel built in Chattanooga by Combustion Engineering, Inc., for America's first full-scale nuclear power station, was shown recently to members of the nation's press, leaders of the business world, and representatives of the Atomic Energy Commission and Government.

The vessel, a huge steel container (see Figs. 1 and 2) in which the nuclear reaction takes place, was built for the atomic power plant at Shippingport, Pa., which Westinghouse Electric Corp. has designed under contract with the AEC. The station will be operated by the Duquesne Light Co. and is scheduled to go in service next year with an initial net electrical output of 60,000 kw. A turbine-generator of 100,000 kw capacity will be installed in anticipation of the possibility of greater nuclear capacity in the future.

"The completion of this 235-ton vessel," said Joseph V. Santry, chairman of Combustion, "marks an important milestone in the nation's policy to develop atomic energy for peacetime uses. The vessel itself is unique in point of safety factors, size, weight and close tolerances. It was two years in the making and involved pioneer work all the way. The steel walls are $8^1/_2$ in. thick, it is three stories high with an inside diameter of 9 ft., and had to be made with a precision never before achieved in equipment of this size."

Behind this chapter in atomic history, it was revealed, is a story of unique cooperation by scientists and engineers representing both government and industry intent on putting the atom to work constructively for people in everyday life.

Design and Fabrication

Commenting on the unusual problems encountered in the design of the vessel, Martens H. Isenberg, president of Combustion, said: "Previously established formulas for determining stresses and thicknesses were no longer applicable in a vessel with the thicknesses of plate and forgings involved. As a result of the design, development, and manufacturing experience on this project, it is anticipated that new criteria and new formulas will be standardized in order to facilitate future design of such equipment.

"Some idea of the manufacturing problems can be gained by realizing that the parts making up the vessel were the largest and heaviest of their kind ever made. The procurement of plate material, one of the most difficult problems of the program, involved getting very thick and heavy stainless-steel clad plates with integral bond between the clad and backing plate. After being rolled, the plate was examined over every square inch of its surface by ultrasonic methods of inspection for integrity of both bond and backing plate. All of the

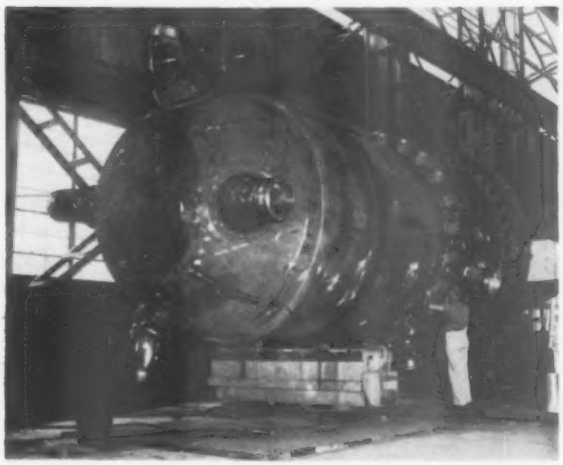


Fig. 1 View of the 235-ton Shippingport reactor vessel showing four 15" I.D. inlet nozzles

Fig. 2 Another view of reactor shell while in process of being positioned

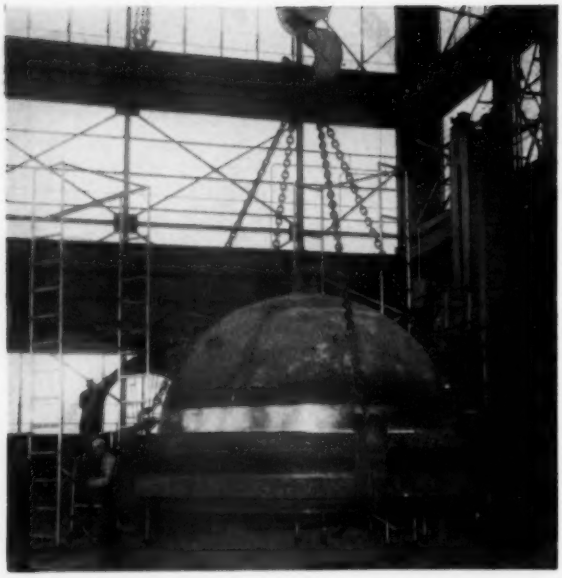


Fig. 3 View of 85-ton removable head, hemispherical portion of which will have 46 openings for fuel handling equipment, instrument leads and control rods

Fig. 4 View showing bolts for holding head to main vessel. There are 42 bolts 80½" high, 6" diameter, weighing 700 lb. each including nuts

welding operations, through thicknesses in some sections up to 10 in., had to be performed while the parts were kept hot, thereby increasing the difficulties of fabrication."

New methods had to be devised to cope with problems that arose during the fabrication of the vessel. Every weld joining the various parts was X-rayed by the company's 15-million-volt betatron, a machine so sensitive that it can find defects as small as a pinhead that might be buried in a steel plate 10 in. thick. All the backing plate surfaces were inspected with a magnetic particle test to insure against any minute flaws.

The vessel is designed to withstand an internal pressure of 2500 lb. per sq. in. at 600°F. The dry weight of the vessel is 235 tons, of which the shell portion itself weighs 150 tons. The removable top head weighs 85 tons (see Fig. 3) and is fastened to the body by means of 42 bolts, 6 in. in diameter, that stand taller than a man(see Fig. 4). In addition the vessel will contain thermal shields, a core assembly and other equipment having a total weight of an additional 100 tons. The final machining operation, requiring two months on one of the world's largest boring mills, was performed with "optical methods" to align matching machined surfaces with maximum accuracy.

Shipping

The vessel was shipped by rail to the Shippingport power plant 25 miles outside of Pittsburgh (see Fig. 5). Originally it was planned to ship it by barge, but limitations in the capacity of floating cranes in the Pittsburgh area prevented this.

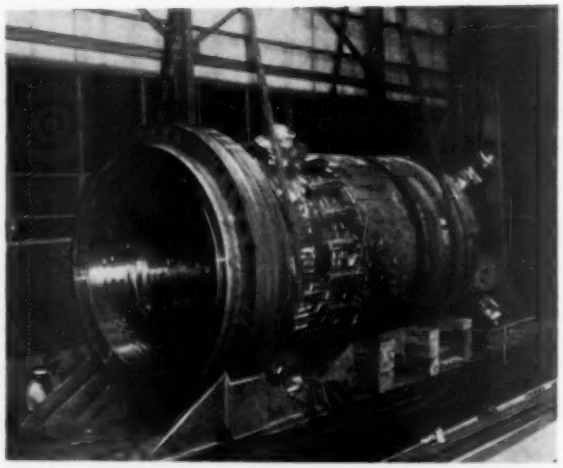


Fig. 5 View of vessel on 24-wheel special flat car showing heavy manganese-molybdenum forged-steel flange

By traveling a circuitous route, traffic officials found they could move the vessel by rail although the trip covered 1075 miles compared to the 365 miles airline distance from Chattanooga to Pittsburgh. Accompanied by project engineers and AEC couriers, as is customary with shipments of this size and weight, the shipment took about two weeks. Rigid speed restrictions (maximum speed, 25 mph) applied throughout the trip, and it was necessary to move the vessel on a special train with all adjacent tracks cleared of cars.

Society News

The Adams National Meeting—A Tribute to Comfort Avery Adams, AWS First President and Founder

Too often, we wait too late to honor those to whom we are indebted. While it is a laudable thing to create activities, scholarships and the like to keep alive the memory of one who may have been a benefactor, a prime organizer or an originator, it is far better, when time still permits, to honor that important someone within the span of his life.

During the past few years, we have anxiously awaited for the most appropriate time and place when and where we could honor, in fitting ceremony, Dr. Comfort Avery Adams, our first president and a founder of the AMERICAN WELDING SOCIETY.

That opportunity, that time and that place have now joined in incidence—Philadelphia, Pa., during the second week of April of this year. On April 8 through 12, the welding industry, its scientists, its engineers, its production men and all others engaged therein, will join in extraordinary convention; exposition, technical meetings, conferences and social activities. Members and guests of both the AMERICAN WELDING SOCIETY and the Electric Welding Committee of the American Institute of Electrical Engineers, will attend, meet and confer in sessions of mutual interest; also, they will view the progress of our industry through the exposition of its equipment and processes.

Dr. Adams' activities and interests have enriched the endeavors of both AWS and AIEE. His works have been recognized, acknowledged, appreciated and cited by many other national and international scientific and engineering groups and organizations. Many industries have benefited greatly from his exhaustive studies, reports and papers.

In honor of our first president, his name has been given to the 1957 AWS National Spring Meeting. Thus, the latter will be known as the Adams National Meeting. Special honorary activities will take place, including the Adams National Dinner on Monday evening, April 8th.

The Fifth Welding Show will be the largest in the history of this event. More new welding products will be shown here than ever before at any show. The show is a complete sell-out, without any available space being left.

The exposition will encompass about 30,000 sq ft of displays—a record-breaking area, about 30% larger than the fabulous Buffalo show in 1956. Attendance is expected to exceed the 10,000 mark for the first time. Hundreds of experts from every leading firm producing welding equipment, supplies or accessories, will be on hand to answer visitors' questions and to suggest new quality methods and cost-reducing techniques.

Visitors will be able to inspect a host of welded products in the "Delaware Valley Welded Products Display." The Philadelphia Section has spent months gathering products of particular interest to welding engineers. Drawn from one of the richest industrial areas of the country, the products will give visitors a new perspective of the potential of the art and science of welding.

In 1957, there will be only one national welding gathering under the sponsorship of the SOCIETY. The Fifth Welding Show will be the only show and the Adams National Meeting will be the only national technical meeting. There will be no National Fall Meeting in 1957. A total of 54 formal papers will be presented in Philadelphia.

Two plant tours in the Philadelphia area and informal panel discussions, when added to other events, will provide a concentration of educational events.

One of the highlights will be the Conference on Electric Welding being held under the sponsorship of the American Institute of Electrical Engineers, which recently awarded its 1956 Edison Medal to Dr. Adams. This conference will consist of three technical sessions, one on arc welding and two on resistance welding.

DeWitt C. Smith, chief metallurgist, Harnischfeger Corp., Milwaukee, will deliver the 1957 Adams Lecture. His subject will be "Evolution of High-Tensile Weld Metal with Low-Hydrogen Electrodes."

Colleges, university schools of engineering, and vocational high schools have been invited to send interested students to the show and to the informal panel discussions. Factories have been urged to send not only their senior welding engineers, but also their junior executives, foremen and supervisors, and anyone else who is employed in a welding capacity.

Thus, from an educational standpoint, those attending the Fifth Welding Show and the Adams National Meeting will be able to learn something about welding at any level of education and experience.

They will see: • Thousands upon thousands of pieces of equipment, supplies and accessories;
• The most modern plants employing modern welding techniques;
• The diversified products produced through welding.

They will hear: • Engineers and researchers deliver papers on the latest developments in the science of welding;
• Practical discussions on welding in terms anyone can understand.

In addition, they will have many opportunities to observe all types of welding equipment in actual operation.

Virtually all equipment will be on live demonstration under simulated factory conditions.

There will also be sufficient opportunity for relaxation and the renewing of old acquaintances. The show and the informal panel discussions will take place at Convention Hall; the Adams National Meeting and other SOCIETY events will be held in the newest hotel in the country, the luxurious Sheraton Hotel. An appropriate program to entertain the ladies has also been arranged.

The Adams National Meeting

We are happy to disclose the advent of the Adams National Meeting. We know that all in the welding and electrical industries—who not only may know Dr. Adams personally but may have been interested in or profited from his teachings—will, with pleasure, join with us in honoring our First President and Founder.

THE AMERICAN WELDING SOCIETY

TECHNICAL PAPERS SESSIONS

1957 AWS ADAMS NATIONAL MEETING and AIEE ELECTRIC WELDING CONFERENCE

APRIL 8-12 • SHERATON HOTEL, PHILADELPHIA, PA.

REGISTRATION

Delaware Valley Suite
SHERATON HOTEL

Sunday, April 7
3:00 P.M. to 6:00 P.M.
Monday, April 8
8:00 A.M. to 4:00 P.M.
Tuesday, April 9
8:00 A.M. to 4:00 P.M.
Wednesday, April 10
8:30 A.M. to 4:00 P.M.
Thursday, April 11
8:30 A.M. to 1:00 P.M.
Friday, April 12
8:30 A.M. to 12:30 P.M.

APRIL 8, MONDAY MORNING

West Ballroom

10:00 A.M.—Official Opening
Address—J. J. Chyle, President, AWS
National Business Meeting—Officer Induction Session
National Awards
Adams Lecture—*Evolution of High-Tensile Weld Metal with Low-Hydrogen Electrodes*
by D. C. Smith, Harnischfeger Corp.

APRIL 8, MONDAY AFTERNOON—2:00 P.M.

Three Simultaneous Sessions

1. NUCLEAR REACTORS AND IRRADIATION EFFECTS

West Ballroom

Chairman—Frank W. Davis
Atomic Energy Commission
Co-Chairman—R. D. Wylie
Babcock & Wilcox Co.

A. Effects of Neutron Radiation on the Mechanical Properties of Some Structural Steels

by ELMER E. BALDWIN, General Electric Co.

B. Effect of Irradiation on Weldability of ASTM A212, Grade B

by WENDELL R. HUTCHINSON, Westinghouse Electric Corp.

C. Inert-Gas Tungsten-Arc Butt Welding of Zircaloy-2 Tubes

by J. W. LINGAFELTER, General Electric Co.

2. WELDABILITY AND RESEARCH

East Ballroom

Chairman—DeWitt C. Smith
Harnischfeger Corp.
Co-Chairman—
Walter H. Wooding
Philadelphia Naval Shipyard

A. Atmospheric Water Vapor Effects on D-C Arc Electrode Burn-Off Rates

by R. H. BENNER, Johns Hopkins University, and T. BENJAMIN JONES, Bell Telephone Laboratories

B. Corrosion Resistance of Type 20 and Type 20 Cb Stainless Steel Welds

by HALLOCK C. CAMPBELL, THOMAS J. MOORE, Arcos Corp., and S. E. TYSON, Carpenter Steel Co.

C. Problems Associated with the Welding of T-1 Steel

by PERRY C. ARNOLD, Chicago Bridge & Iron Co.

3. APPLICATIONS

Pennsylvania Ballroom (West Section)

Chairman—Sidney Low
The Chapman Valve Mfg. Co.
Co-Chairman—Roger I. Fluck
Bethlehem Steel Co.

A. Welding and Related Procedures Encountered in a Modern Steel Foundry

by SAMUEL W. GEARHART, JR., Birdsboro Steel Foundry and Machine Co.

B. Flame Washing of Steel Castings

by A. F. CHOUINARD, National Cylinder Gas Co.

C. Rockets for Steel Hardening

by JAMES A. BROWNING, Dartmouth College

APRIL 9, TUESDAY MORNING—9:30 A.M.

Three Simultaneous Sessions

4. NUCLEAR REACTORS AND IRRADIATION EFFECTS

West Ballroom

Chairman—W. L. FLEISCHMANN
General Electric Co.
Co-Chairman—ROGER SUTTON
International Nickel Co.

A. Welding Problems in Pressure Vessels for Nuclear Reactors

by R. E. LORENTZ, JR., Combustion Engineering, Inc.

B. Designing and Fabricating the APDA Reactor Vessel

by D. O. LEESER, D. J. SENGSTAKEN, Atomic Power Development Associates, Inc., and C. T. WARD, Combustion Engineering, Inc.

C. Peripheral Welding of Internally-Clad Steel for Nuclear Reactor Application

by W. J. LEONARD and J. C. THOMPSON, JR., Union Carbide Nuclear Co.

5. RESISTANCE WELDING

East Ballroom

Chairman—PAUL G. NELSON
The Budd Co.
Co-Chairman—EDMAN F. HOLT
P. R. Mallory & Co., Inc.

A. Tip-Life Studies in the Spot Welding of 5052 Aluminum Alloy

by RICHARD A. DAVIS and ROBERT C. McMASTER, Ohio State University

B. Spot Welding 65-35 Brass on Single-Phase Equipment with Slope Control

by LORING E. MILLS and HARRY C. WOLFE, General Electric Co.

C. Electrode Tip-Life Studies in Series Spot Welding

by E. F. NIPPES, W. F. SAVAGE, S. M. ROBELOTTO and K. E. DORSCHU, Rensselaer Polytechnic Institute

6. RESEARCH AND APPLICATION

Pennsylvania Ballroom (West Section)

Chairman—ARTHUR A. HOLZBAUR
Sun Shipbuilding & Dry Dock Co.
Co-Chairman—THOMAS J. GRIFFIN
Bureau of Ships

A. Stress Corrosion Cracking of Titanium Weldments

by W. L. ARTER and R. MEREDITH, North American Aviation, Inc.

B. Bonded Fluxes for Submerged-Arc Welding of Alloy Steels

by HALLOCK C. CAMPBELL, Arcos Corp., and WALLACE C. JOHNSON, Welding Consultant

C. Inert-Gas Tungsten-Arc Spot-Welding of an Automatic Transmission Subassembly

by W. G. MERTENS and O. J. RYDER, Detroit Transmission Division, General Motors Corp.

APRIL 9, TUESDAY AFTERNOON—2:00 P.M.

Three Simultaneous Sessions

7. RESISTANCE WELDING

West Ballroom

• This session is sponsored by the Committee on Electric Welding of AIEE

Chairman—M. P. CORNELIUS
International Harvester Co.

A. Design of Largest Frequency Converter Unipolar Resistance Spot Welder

by J. F. DEFFENBAUGH and F. E. MURRAY, Federal Machine and Welder Co.

B. New Techniques in Precision Welding Control

by J. L. SOLOMON and M. BALIKOV, Sciaky Bros., Inc.

C. A New Basic Component for Electronic Resistance Welding Control—A High Performance Relay

by E. B. McDOWELL, General Electric Co.

8. WELDABILITY AND RESEARCH

East Ballroom

Chairman—ALAN E. FLANIGAN
University of California
Co-Chairman—MARION F. COUCH
Bethlehem Steel Co.

A. Sulfur and Phosphorus versus Hot Ductility of Mild-Steel Weld Metals

by A. L. LOWE, JR., P. J. RIEPPEL and R. P. SOPHER, Battelle Memorial Inst.

B. Relative Behavior of Notch-Toughness Tests for Welded Steel

by W. J. MURPHY, W. D. McMULLAN and R. D. STOUT, Lehigh University

C. Welding of High-Strength Pressure-Vessel Steels in Heavy Sections

by A. P. BUNK, Chicago Bridge & Iron Co.

9. STRUCTURES

Pennsylvania Ballroom (West Section)

Chairman—JOHN E. SOUTH
Pennsylvania Railroad Co.
Co-Chairman—JAMES L. WALMSLEY
Bethlehem Steel Co.

A. Stress Conditions in Welded Structural Connections Subjected to Impact Loading

by PAUL J. BRENNAN and HARRY A. B. WISEMAN, University of Delaware

B. The Plastic Behavior of Structural Members and Frames

by GEORGE C. DRISCOLL, JR., LYNN S. BEEDLE, Lehigh University

C. A Short Course in Welded Rigid-Frame Design

by MARTIN P. KORN, Consulting Engineer

APRIL 10, WEDNESDAY MORNING—9:30 A.M.

Three Simultaneous Sessions

10. RESISTANCE WELDING

West Ballroom

• This session is sponsored by the Committee on Electric Welding of AIEE

Chairman—R. P. C. RASMUSEN
Battelle Memorial Institute

A. A New Welder Busway Distribution System

by R. W. DAILEY, Chrysler Corp., and L. E. FISHER, General Electric Co.

B. Save Air and Improve Gun Welding Performance

by J. W. BROWN, Square D Co.

C. The Proximity Limit Switch—A Versatile Tool for Industry

by R. C. MIERENDORF, Square D Co.

11. WELDABILITY AND RESEARCH

East Ballroom

Chairman—W. D. DOTY
U. S. Steel Corp.
Co-Chairman—R. W. CLARK
General Electric Co.

A. Arrest of Brittle Fractures in Wide Steel Plates

by ROBERT J. MOSBORG, WILLIAM J. HALL and WILLIAM H. MUNSE, University of Illinois

B. Design—Its Influence on Residual Stress and Brittle Fracture

by JOSEPH L. THOMAS, Pullman Standard Car Manufacturing Co.

C. Stress Relieving of Weldments

by EARL R. PARKER, University of California

12. DESIGN AND APPLICATIONS

Pennsylvania Ballroom (East Section)

Chairman—L. J. LARSON
Allis-Chalmers Mfg. Co.
Co-Chairman—R. J. KELLER
A. O. Smith Corp.

A. Joint Design for Making Root-Pass Welds Without Filler Metal

by W. R. SMITH and L. C. LEMON, General Electric Co.

B. Welded Design for Improved Vibration Control

by OMER BLODGETT, Lincoln Electric Co.

C. Boiler Code Welding and Joint Design with the CO_2 Process

by J. D. CAREY, JR., General Electric Co.

APRIL 11, THURSDAY MORNING—9:30 A.M.

Three Simultaneous Sessions

13. ARC WELDING

West Ballroom

• This session is sponsored by the Committee on Electric Welding of AIEE

Chairman—W. J. GREENE
Air Reduction Research Lab.

A. Electrical Requirements for Automation in Arc Welding

by R. W. TUTHILL and R. D. MANN, General Electric Co.

B. Factors That Effect Metal Transfer with Gas-Shielded Arc Welding

by A. LESNEWICH, Air Reduction Co., Inc.

C. Experimental Welding with Cone Arc

by R. E. MONROE and D. C. MARTIN, Battelle Memorial Institute

14. TITANIUM AND ZIRCONIUM

East Ballroom

Chairman—C. E. HARTBOWER
Watertown Arsenal Laboratory
Co-Chairman—L. R. HONNAKER
E. I. du Pont de Nemours & Co.

A. Effects of Interstitials on Weldability of 6A1-4V and 7A1-3Mo Titanium Alloys

by JOHN RUDY, J. B. McANDREW and HARRY SCHWARTZBART, Armour Research Foundation

B. Arc Welding of Vacuum and Inert-Atmosphere Melted Zircaloy-2

by HOWARD C. LUDWIG, Westinghouse Research Laboratories

C. Corrosion Resistance of Zircaloy-2 Brazements in High-Temperature Water

by J. B. McANDREW, R. NECHELES and HARRY SCHWARTZBART, Armour Research Foundation

15. BRAZING

Pennsylvania Ballroom (West Section)

Chairman—HARRY V. INSKEEP
Linde Air Products Co.
Co-Chairman—LESTER E. ABBOTT
Bell Telephone Labs., Inc.

A. NiCrB Brazing of a High-Temperature Alloy

by GEORGE AGGEN, EDWARD E. REYNOLDS, Allegheny Ludlum Steel Corp., and ROGER A. LONG, Ferrotherm Co.

B. Alloys for Brazing Thin Sections of Stainless Steel

by ALLEN S. McDONALD, Handy & Harman

C. Self-Fluxing, Airproof Brazing Alloys

by NIKOLAJS BREDZS, Armour Research Foundation of Illinois Institute of Technology

APRIL 12, FRIDAY MORNING—9:30 A.M.

Three Simultaneous Sessions

16. GAS-SHIELDED WELDING

West Ballroom

Chairman—A. U. WELCH
General Electric Co.
Co-Chairman—W. H. HELMBRECHT
Linde Air Products Co.

A. Comparative Study of Thoriated, Zirconiated and Pure-Tungsten Electrodes

by L. P. WINSOR and R. R. TURK, Rensselaer Polytechnic Institute

B. Photographic and Oscillographic Studies of Welding Arcs in Helium, Argon and Carbon Dioxide

by THOMAS H. HAZLETT and GEORGE M. GORDON, University of California

C. Automatic Inert-Gas Tungsten-Arc Welding of Aluminum Alloys

by HARRY D. MANN, Air Reduction Sales Co., and RAWLINS E. PURKHISER, Airco Equipment Manufacturing Division

17. PRESSURE VESSELS

East Ballroom

Chairman—I. E. BOBERG
Chicago Bridge & Iron Co.
Co-Chairman—C. L. DOOLEY
Sun Shipbuilding & Dry Dock Co.

A. Weld Cladding of Carbon and Low-Alloy Steels Steel

by R. V. FOSTINI, J. W. FLANNERY and W. R. APBLETT, JR., Foster Wheeler Corp.

B. Effect of Plastic Fatigue on Pressure Vessel Materials and Design

by LAMBERT F. KOOISTRA, Babcock & Wilcox Co.

C. Fatigue Resistance of Simulated Nozzles in Model Pressure Vessels

by GEORGES WELTER and JULIEN DUBUC, École Polytechnique

18. SURFACING, BRAZING AND SOLDERING

Pennsylvania Ballroom (East Section)

Chairman—A. N. KUGLER
Air Reduction Co., Inc.
Co-Chairman—BYRON D. GATES
The Budd Co.

A. Mechanized Surfacing with Alloy Materials

by J. H. NEELY and R. S. ZUCHOWSKI, Linde Air Products Co.

B. Thermal Analysis of Brazing and Hard Surfacing Alloys—A Proposed Method

by FORBES M. MILLER, Wall Colmonoy Corp.

C. Zinc Soldering of Aluminum

by I. B. ROBINSON, Aluminum Company of America

EDUCATIONAL LECTURE SERIES

Pennsylvania Ballroom (East Section)

MONDAY, APRIL 8, 4:30 to 6:00 P.M.

TUESDAY, APRIL 9, 4:30 to 6:00 P.M.

Chairman—CLARENCE E. JACKSON
Linde Air Products Co.
Co-Chairman—G. G. LUTHER
Air Reduction Co. Inc.

Weldability of Structural Materials

by WILLIAM S. PELLINI, Naval Research Laboratory

SYMPOSIUM ON EDUCATION

West Ballroom

WEDNESDAY, APRIL 10, 2:00 P.M.

Chairman—CLARENCE E. JACKSON,
Linde Air Products Co.
Co-Chairman—H. O. SOSNIN, Tube Turns, Inc.

Educational Levels of Welding

Keynote Address—by DR. HOWARD L. BEVIS, Chairman, National Committee for the Development of Scientists and Engineers, Washington, D. C.

Welding at Apprentice Level, by M. M. HANSON, U. S. Dept. of Labor, Bureau of Apprenticeship, Washington, D. C.

Welding at the Supervisor Level, by H. E. BALDWIN, Le Tourneau-Westinghouse Co., Peoria, Ill.

Welding at the College Level, by R B. McCAULEY, Ohio State University, Columbus, Ohio

OTHER ACTIVITIES

APRIL 8, MONDAY

6:00 P.M.—President's Reception in East Ballroom of Sheraton Hotel
8:00 P.M.—Adams National Dinner in West Ballroom of Sheraton Hotel. Historical pageant: "From Gas Light Through Arc Light"

APRIL 9, TUESDAY

9:30 A.M.—Welding Promotion Conference in Constitution Room of Sheraton Hotel
2:00 P.M.—National Membership Committee Meeting in Room 548 of Sheraton Hotel
2:30 P.M.—Manufacturers Committee Meeting in Constitution Room

APRIL 10, WEDNESDAY

12:30 P.M.—NWSA Luncheon Meeting in Pennsylvania Ballroom (West Section) of Sheraton Hotel
RWMA Luncheon Meeting in Independence Room of Sheraton Hotel
2:00 P.M.—Annual Business Meeting—Activities Report Session in Constitution Room of Sheraton Hotel
3:30 P.M.—Open Meeting of National Nominating Committee in Constitution Room of Sheraton Hotel
4:30 P.M.—Section Officers Meeting in Pennsylvania Ballroom (East Section) of Sheraton Hotel
7:00 P.M. Ohio State University Student Alumni Dinner in Constitution Room of Sheraton Hotel

APRIL 11, THURSDAY

10:00 A.M.—Board of Directors Meeting in Independence Room of Sheraton Hotel
12:30 P.M.—Sustaining Member and Board of Directors' luncheon meeting in Constitution Room of Sheraton Hotel

INFORMAL PANEL DISCUSSIONS

CONVENTION HALL—EXHIBIT FLOOR—*North Exhibition Hall*

TUESDAY, APRIL 9—2:00 P.M.

Panel Session on Arc Welding, covering Manual-arc, Submerged-arc and Inert-gas Welding
Chairman: Walter Mehl, Heintz Manufacturing Co.

WEDNESDAY, APRIL 10—2:00 P.M.

Panel Session on Gas Welding and Cutting
Chairman: Walter Shire, New York Shipbuilding Corp.

PLANT TOURS

• **Tuesday, April 9**—Tour of the Fairless Works of the U. S. Steel Corp. at Fairless, Pa.: Visit will extend not only to the departments where steel is produced, but also to the Welding Shops where all welding repairs, hard-surfacing operations and structural welding are performed.

• **Wednesday, April 10**—Tour of Westinghouse Electric Corp., South Philadelphia Works, Steam Turbine Division. The fabrication and welding of the industrial and central station steam turbine equipment will be witnessed, including the welding of high-alloy and low-alloy steel with automatic and manual processes. Visitors must be United States citizens. Registration cards must be filled out on Tuesday, April 9.

• Each tour is a morning tour. Everyone will return in time for lunch and afternoon sessions.

LADIES' PROGRAM

SUNDAY, APRIL 7

3:00–6:00 P.M.	Ladies' Reception in Delaware Valley Suite "C" and "D" of the Sheraton Hotel where refreshments will be served.

MONDAY, APRIL 8

8:30–4:30 P.M.	Registration in Connie Mack Room of the Sheraton Hotel.
9:00 A.M.	Coffee Hour in Connie Mack Room.
2:00 P.M.	Afternoon tea and bridge party in the Connie Mack Room.
6:00 P.M.	President's Reception in East Ballroom
8:00 P.M.	Adams National Dinner in West Ballroom.

TUESDAY, APRIL 9

8:00–4:00 P.M.	Registration in Connie Mack Room.
9:00 A.M.	Coffee Hour in Connie Mack Room.
10:30 A.M.	Buses will leave Sheraton Hotel for a historical tour of Philadelphia.
12:30 P.M.	Luncheon will be served at the Parkway House.

WEDNESDAY, APRIL 10

8:00–4:00 P.M.	Registration in Connie Mack Room.
9:00 A.M.	Coffee Hour in Connie Mack Room.
12 Noon	Luncheon in Connie Mack Room.
1:00 P.M.	Buses will leave for tour of Radio-TV Station WCAU. Following tour the ladies are invited to attend popular program, "Cinderella Week End."

THURSDAY, APRIL 11

8:30–4:00 P.M.	Registration in Connie Mack Room.
9:00 A.M.	Coffee Hour in Connie Mack Room.
12 Noon	Luncheon will be served at the old Bookbinders Restaurant, very famous Philadelphia Seafood House.
2:00 P.M.	Matinee theater performance.

FRIDAY, APRIL 12

8:30–12:30 P.M.	Registration in Connie Mack Room.
9:00 A.M.	Coffee Hour in Connie Mack Room.

Monday subscription is $1.00; other days (Tuesday through Thursday) $4.25 per event or package arrangement of $13.00 for participation in the entire week's program.

WELDING SHOW EXHIBITS AND DEMONSTRATIONS

CONVENTION HALL

Hours of the Exposition

Tuesday, April 9	*12:00 Noon to 10:00 P.M.*
Wednesday, April 10	*10:00 A.M. to 10:00 P.M.*
Thursday, April 11	*10:00 A.M. to 6:00 P.M.*

Admission by registration

HIGHLIGHTS OF EXHIBITS AT 1957 WELDING SHOW

CONVENTION HALL PHILADELPHIA, PA.

APRIL 9-11

Air Reduction Sales Co.
Booth Nos. 330, 334, 431 & 435

Feature: Aircomatic spot-welding attachment for standard Aircomatic manual guns; manual and machine Heliweld holders; lime-coated stainless electrodes; selenium rectifier and motor-generator arc welding machines. Also, display of other products.

Alloy Rods Company
Booth Nos. 101–105

Live demonstrations of Wear-Arc iron-powder hard-surfacing alloys, and of Wear-O-Matic hard-surfacing wire for automatic and semiautomatic applications. Also, display of complete line of alloy welding electrodes.

All-State Welding Alloys Co., Inc.
Booth No. 442

Feature: Commercial alloys to weld, braze, and solder aluminum to aluminum and aluminum to dissimilar metals, including fluxless rub-on solder and super-cleaned spooled aluminum wire. Also, flux-coated bronze.

Aluminum Company of America
Booth No. 231

Feature: Live demonstrations of both consumable electrode welding and arc cutting of the aluminum alloys. Also, comprehensive exhibit of welded aluminum construction.

American Manganese Steel Div.
Booth No. 106

Live welding demonstration showing a semiautomatic hard-surfacing machine in operation. Also, display of general Amsco line of hard-surfacing products and manganese weldments.

American Platinum Works
Booth No. 623

Feature: Working demonstration of metal joining with "Silvaloy" silver-brazing alloys and APW fluxes using both automatic turntable and oxyacetylene torch.

American Pullmax Co., Inc.
Booth No. 500

Feature: Pullmax universal welding and farming machines for straight shearing, dishing, joggling, beading, louvering and slot cutting in all types of ferrous and nonferrous metals.

American Torch Tip Co.
Booth No. 627

Feature: Introduction of new patented multi-use adapters and tips; also, display of standard line of cutting and scarfing tips.

Ampco Metal, Inc. **Booth No. 615**

Feature: Complete line of bronze Weldrod and resistance welding products; electrodes, filler rod and wire; welding tips, wheels, dies and holders; holder-to-tip adaptors, quick dis-connect shut-off couplings, etc.

Ampower Products Co.
Booth No. 543

Feature: New 1957 air-powered and water-cooled portable production spot welder Model No. 57. Also, display of Model No. 55 semi-production portable spot welder and all new attachments and accessories.

Arcos Corp. **Booth Nos. 230 & 234**

Demonstration of submerged-arc welding of stainless and alloy steels with Arcosite flux and Chromenar bare electrodes. Also, color sound film, "Consumable Insert Welding," showing roof passes in pipe welding.

"Aro" Spot Welder Div.
Booth No. 300

Display of full line of "Aro" portable spot welders, including new model P-298. All models shown in live demonstration, particularly the air and air-hydraulic models.

Aronson Machine Co. **Booth No. 434**

Feature: Display of new line of geared elevating positioners and various bench type positioners designed for the latest welding processes.

Balteau Electric Corp. **Booth No. 307**

Display of new models of "Baltospot" X-ray unit and light 200 kv unit; also Baltograph 180 KV, 10 MA, beryllium window, which may be equipped with 180 KV, 4 MA, 360° anode, air-cooled.

Banner Welder, Inc. **Booth No. 517**

Feature: Display of heavy duty spot-projection type welder and versatile spot welder. Also, distribution of new literature describing the latest welder designs.

Bay State Abrasive Products Co.
Booth No. 614

Display and demonstration of complete line of portable grinding wheels for the welding industry, including reinforced raised hub disk-wheels, straight wheels, cup wheels, cones, mounted wheels and abrasive disks.

Bernard Welding Equipment Co.
Booth No. 218

Feature: Live demonstrations of rugged, new semiautomatic equipment for use with all types of gas-shielded processes; also, a new self-contained coolant system for such processes.

Cam-Lok Division, Empire Products, Inc.
Booth No. 440

Display of new molding kit which will produce waterproof, shockproof splices for welding cable; also, waterproof, shockproof cable connections as well as standard lines of cable connections, electrode holders, etc.

Cayuga Machine and Fabricating Co., Inc. **Booth No. 404**

Feature: Display of new Cayuga center-post-design positioners, standard turning rolls, ram pedestal manipulator, and seamer; also photographs of special automation machinery.

Champion Rivet Co. **Booth No. 313**

Feature: Exhibit of full Champion line of iron-powder electrodes and several electrodes of the low-alloy type.

Clementina, Ltd. **Booth No. 609**

Feature: Demonstration of Clemco "Educt-O-Matic" self-contained portable blast unit; dry blast abrasive cleaning cabinets, suction type blasting. Also, display of venturi-style nozzles, sandblast machines and remote controls for them.

Coast Metals, Inc. **Booth No. 308**

Feature: Display of samples of such materials as surfacing welding rod, automatic wires, new brazing powders, alloy testing.

Conner Steel Products **Booth No. 628**

Display of Conner standard prefabricated parts for weldments: weldment components intended to eliminate hand finishing, and to strengthen, modernize and improve structure of a wide variety of weldments.

Contour Marker Corp. **Booth No. 235**

Feature: Contour marker, doing layout work on pipe and structural steel; Boyce centering head for locating centerlines, etc.; pipe flange aligner; and 24-in. radius marker for circles.

Dockson Corp. **Booth No. 212**

Feature: Initial showing of a new two-stage regulator. Of all-brass construction, this regulator has many unique features including simplicity and low cost.

Erico Products, Inc. **Booth No. 605**

Feature: Complete line of "Caddy" air welding accessories plus seven new models "Caddy" toggle clamps.

Eutectic Welding Alloys Corp.
Booth Nos. 200 & 204

Feature: New products—flux for residue—free oxyacetylene fabrication with bare rods; new EutecRods, EutecTrodes for aluminum, steel, cast iron. Other products—"Low-temperature" welding alloys and fluxes.

Federal Machine & Welder
Booth No. 506

Feature: New-design RWMA size No. 1 press-type spot welder. Also, cut-away model of new-design molded diaphragm or cylinder assembly for aircraft welders. Complete films of fully automated welder lines.

Fibre-Metal Products Co.
Booth No. 526

Feature: New "Superlite" aluminum safety hats with polyethylene suspension; revolutionary Fiberglas "Wide-Vision" welding helmets; rigid, single-cup headrest "Sologoggles"; "Supergard" Fiberglas safety hats and caps; also, live "Weld-Prober" demonstration.

Frommelt Industries **Booth No. 630**

Display of "Spa-Fla," UL approved spark-flash portable safety welding shield, welding booths, windbreaks, and welding curtains; also, "Spa-Fla" with "Ray-Tex" aluminum-coated fabric, and "Ray-Foil" protective heat cloth.

General Electric Co.
Booth Nos. 322 423

Feature: Automatic Fillerarc equipment with new oscillating head for overlay and hard-surfacing work; semi-automatic Fillerarc with spot-welding attachment. Also, complete line of arc-welding equipment, plus electrodes and accessories.

Graham Manufacturing Corp.
Booth No. 512

Feature: Display of completely automatic, hopper fed, specialized stud-welding equipment, including a newly developed hopper mechanism that can be attached to most standard bench machines.

Handy & Harman **Booth No. 534**

Feature: Live, high-production silver-brazing job demonstrating how "Easy-Flo" makes strong, leak-tight joints which resist vibration, pressure, and chemical corrosion. Also, display of "Hi-Temp" brazing alloy series.

Harnischfeger Corp. **Booth No. 523**

Display of welding-positioners of 500 and 1000-lb capacity, and four welders—ac, ac- dc with built-in spot gun controls, dc constant voltage and 200 amp gas engine portable.

Harris Calorific Co. **Booth No. 635**

Feature: Live demonstration showing the advantages of natural gas, or liquified petroleum gases, as compared to acetylene for flame cutting.

Haynes Stellite Co. **Booth No. 417**

Feature: New drawn-tube wire for hard surfacing and weld properties of Haynes high-temperature and corrosion-resistant alloys.

Hobart Brothers Co. **Booth No. 100**

Demonstration of newly-developed arc-welding equipment, both manual and automatic. Display of new type dc rectifiers, ac-dc welder combinations, ac-dc inert-gas equipment, ac "Diverter Path" transformers and other equipment.

Holger Andreasen, Inc. **Booth No. 408**

Feature: New "Andrex" 130 kv portable X-ray unit with tube head weighing approximately 50 lbs. Also, display of other "Andrex" portable X-ray equipment, including units in capacities 160 kv, 200 kv and 260 kv.

Industry & Welding **Booth No. 214**

Feature: Copies of "Industry & Welding" and "Welding Illustrated" for distribution; information on type and quality of people generally responsible for purchase of welding equipment and supplies. Market data also available.

International Nickel Co., Inc.
Booth Nos. 327 & 331

Feature: Welding demonstrations of many dissimilar alloy combinations with Inco Rod "A"; Ni-Rod "55" electrodes for cast irons; and complete line of electrodes, wires and fluxes for welding high-nickel alloys.

Jackson Products
Booth Nos. 539 & 541

Feature: New among arc-welding holders and accessories—a neoprene-insulated cable connector. In safety equipment—the Musketeer, new eye and face shield headgear with four new interchangeable visors.

K-G Equipment Co., Inc.
Booth No. 613

Display of full line of welding and cutting equipment, featuring new flow-meter regulator, the no-flashback cutting torch and other items.

KSM Products, Inc. **Booth No. 504**

Feature: Live demonstrations of stud welding; technical discussions and operation of new stud-welding development—"Mark XI" stud welder operated with integral power source for welding large diameter studs at low cost.

Lenco, Incorporated **Booth No. 107**

Feature: Display of electrode holders using all fiberglas insulation to prevent moisture absorption and offer maximum protection to weldor; engineered for top performance; brilliant colors for safety.

Lewis Welding & Engineering Corp.
Booth Nos. 138 & 239

Feature: Operation of 1957 Model of the standard track-type "Universal" automatic welding head manipulator. Machine will incorporate latest improvements resulting from intensive development program.

Lincoln Electric Co. **Booth No. 316**

Feature: Display and live demonstration of new additions to Lincoln line of manual combination ac- dc "Idealarc" welders; new automatic equipment and techniques; and new manual electrodes.

Linde Air Products Co. **Booth No. 417**

Feature: First public exhibit and live demonstration of new "Unionarc" welding process and equipment. Also, new portable liquid oxygen cylinder; gas and electric welding equipment; and graphical portrayal of gas distribution facilities.

Magnaflux Corp **Booth No. 236**

Display of "Magnaflux" and "Zyglo" inspection equipment; new "Zyglo" ZA-43 and ZA-44 kits for shop or field and leaker inspections; also, "Magnaflux" equipment in action with new labor-saving accessories.

P. R. Mallory & Co., Inc.
Booth No. 527

Feature: Display of resistance welding

electrodes, holders and fixtures of various types; demonstration of these items on an actual spot welder. Names of prominent users will be colorfully featured.

Marquette Manufacturing Co.
Booth No. 513

Display of "Jet" series oxyacetylene equipment, welding electrodes and gas-welding rods. Feature: New iron-powder, contact-type electrode for hard-surfacing purposes.

McKay Company **Booth No. 130**

Feature: New McKay "Mon-Alloy" welding electrode. Also, display of various other McKay stainless steel, mild steel and hard-surfacing welding electrodes, and tube-alloy welding wire.

Metal & Thermit Corp. Booth No. 508

Feature: Live demonstration of automatic welding using Metal & Thermit constant-voltage welder (C.A.P.S.) and constant-speed wire feed.

Metallizing Company of America
Booth No. 439

Display of metallizing equipment featuring electrically driven (Mogulectric) and magnetic controlled (Mogul Turbo-Jet) metallizing guns. Aluminum oxide and zirconium spraying equipment ("Rokide" coatings). Automatic controls for production metallizing.

Metallizing Engineering Co., Inc.
Booth No. 509

Feature: Operating exhibit of new powder metallizing spray guns. Also, application of hard-surfacing materials, as well as heat barrier ceramics will be covered.

Miller Electric Manufacturing Co.
Booth No. 422

Principal attraction: Live demonstration of automation in welding through the new Miller weld sequence timer and the SR-200WR single range selenium rectifier dc welder. Also, display and demonstration of other equipment.

Modern Engineering Co.
Booth No. 540

Feature: New Meco "Jiffy" acetylene, 2-gage, regulator of machined aluminum; takes MC or B tank coupling; 3/8-inch left-hand hose connection; for air-acetylene torches; compact design; lightweight; adjustable; efficient.

National Cylinder Gas Co.
Booth Nos. 238, 240, 244 & 245

Display of "Torchweld" and "Rego" welding and cutting torches and regulators, "Sureweld" arc welding machines; also, demonstration of latest developments in semiautomatic arc welding.

National Torch Tip Co. Booth No. 135

Feature: New military torch, tip cleaners and propane tips. Also, display of complete line of replacement cutting and welding tips for all equipment and all gases; torches; tip cleaners, etc.

North American Aviation, Inc.
Booth No. 333

Educational exhibit demonstrating relationship of modern welding to latest missile technology, featuring spot-welded stainless steel sandwich for tomorrow's missile skins; plus, new titanium brazing techniques developed by NAA.

North American Philips Co., Inc.
Booth No. 134

Highlight: Electronic fluoroscopy. Daylight-high resolution fluoroscopy of metals—a new concept of industrial X-ray inspection. Also, display of "Norelco" portable and Constant Potential Fractional Focus units.

Ohio Nut And Bolt Co. Booth No. 535

Principal attractions: New RN Weld Nut developed to broaden applications where weld fasteners can be used advantageously; also, resistance welder in operation to demonstrate proper welding techniques for Ohio parts.

Page Steel and Wire Div.
Booth No. 634

Feature: Display of complete line of carbon steel, low-alloy and stainless steel submerged-arc and inert-gas welding wire, acetylene gas and metal spray wire.

Pandjiris Weldment Co. Booth No. 126

Display of Pandjiris 3000-lb capacity positioner, 18,000-lb capacity power turning rolls and semiautomatic manipulator; also, new light-duty series manipulator for full automatic welding heads.

Picker X-Ray Corp. **Booth No. 531**

Display of latest lightweight portable X-ray equipment and portable Iridium and Cobalt equipment for radiography of welds and castings; also, several new models for weld inspection of pressure vessels.

Precision Welder & Flexopress Corp.
Booth No. 301

Feature: Operation of a production-tooled standard press welder, a new model magnetic force welder and a special-purpose high-production welder assembling parts for a consumer product.

Pure Carbonic Co. **Booth No. 242**

Feature: Display of carbon dioxide cylinder banks and other CO_2 supply systems—CO_2 regulators and flowmeters.

J. M. Ragle Industries **Booth No. 137**

Display of sparklighters, tip drill kits, white metal welding rod, soapstone holders, hose and cable measuring machine, chipping hammers, hose crimpers, advertising caps and quilted cloth caps.

Reid-Avery Co., Inc. **Booth No. 530**

Feature: "Raco" Model BW-2 welding head and control; free wheeling reels; low-hydrogen metal-powder electrodes; special electrodes for foundries; five hundred pounds of wire in Lever-Pak for inert-gas welding.

Robotron Corporation **Booth No. 516**

Featured item: Nema Type N2, non-synchronous tube firing resistance welding control with eighty-seven degree, first half cycle firing.

Robvon Backing Ring Co.
Booth No. 636

Feature: Display of approved backing rings for welded pipe, valves and fitting joints; including three patented backing rings as well as many kinds of machined rings manufactured from various metals.

Sciaky Bros., Inc. **Booth No. 339**

Feature: First time on exhibition . . one of Sciaky's largest capacity resistance welders, the PMCO 6STK, which will spot weld to Military Specifications, equipped with Predetermined Electronic Welder Control.

Sellstrom Manufacturing Co.
Booth Nos. 206 & 208

Principal attraction: "Jumbo Welding Goggles," the 620 with a rigid brace bar and the 618 with a flexible bridge. Also, entire line of "Sellstrom Safeguards," eye and face protective equipment.

Sight Feed Generators Co.
Booth No. 304

Feature: Demonstration of new "Rex-arc" automatic welder and positioner for tractor rollers, idlers, other circumferential and conical weldments. Also, "Liquifluxer" for brazing requiring no special torch, no pre- or after cleaning.

A. O. Smith Corp. **Booth No. 405**

Feature: Demonstration of SW15IP, a new extremely-high-speed, all-position iron-powder electrode. Also, physical demonstration of CO86, A. O. Smith's special-formula automatic wire designed particularly for carbon-dioxide applications.

Smith Welding Equipment Corp.
Booth No. 113

Display and demonstration of equipment for cutting, heating and welding.

Feature: "Silver-Star" cutting torches for all types of hand and machine operations; also, new bevel cutting attachment.

Speedi-Burn Products Co.
Booth No. 631

Exhibit of Multiple Bar cutoff machine equipped with automatic starting-wire system. Also, display of Speedi-Burn Model "HS-400" hollow-spindle cut-off machine for contour cutting of pipe.

Square D Company **Booth No. 626**

Feature: Demonstrations of cylinder head mounted four-way valve that saves air and increases welding speed, proximity limit switch that indicates magnetic material 1 in. away.

Stoody Co.
Booth Nos. 139, 143 & 144

Feature: Live demonstrations of automatic electric welding head hard surfacing steel mill run-out table rolls; semi-automatic welder; automatic gas welding machine hard surfacing grader blades. Also, display of hard-surfaced parts.

Sylvania Electric Products, Inc.
Booth No. 210

Feature: Display of tungsten electrodes with color-coded ends. Color code makes it possible to tell the type of rod at a glance, helping to eliminate waste and possible errors.

Taylor-Winfield Corp. **Booth No. 400**

Feature: New models of electric resistance welders on display-press type, spot and projection. Also, special purpose welders in operation, with controls of latest electronic design. Descriptive literature available.

Tempil° Corp. **Booth No. 629**

Trained personnel to demonstrate how Tempil° products indicate temperatures. Sample Tempil° pellets for 325° F made available, free of charge, to visitors so they may try them under actual working conditions.

Tweco Products, Inc. **Booth No. 340**

Feature: Action displays, demonstrating the efficiency and long life of "Tweco-Lite" aluminum welding cable, the *new* design in "Twecotong" electrode holders, and cable connections under actual working conditions.

Uniflex Cable Division, United Metal Craft Co. **Booth No. 640**

Feature: Display of cables, including a water-cooled terminal on an air-cooled jumper; of particular interest to users of multiple-head welding equipment.

Unique Turntable & Equipment Corp.
Booth No. 112

Feature: Latest addition, Model "UM" welding head manipulator. Unique line, now complete, offers turning rolls, positioners, and manipulators.

United Wire & Supply Corp.
Booth No. 305

Feature: Display of over thirty silver and copper phosphorous low-temperature brazing alloys, three types of flux; also, live brazing by torch/induction using both rod and wire preforms.

Velocity Power Tool Co.
Booth No. 335

Features: New type AB battery-ignited "Torch-O-Matic" with automatic finger-controlled ignition for instantaneous lighting. Releasing trigger shuts off gas for economy and safety of operation.

Vickers Electric Division **Booth No. 617**

Live demonstrations of Vickers 400-amp combination welder and cp adapter, with remote controls; new starting and tail slope controller, and new circuit for low-current high-frequency arc initiation.

Victor Equipment Co. **Booth No. 522**

Display and demonstration of all Victor standard and latest flame-cutting and welding apparatus; high-pressure regulators; blasting nozzles; straight-line and shape cutting machines; and hard-surfacing alloy rods.

Wall Colmonoy Corp. **Booth No. 121**

Feature: Live demonstration of new Model "C-2" Spraywelder, redesigned to provide greater flow rate of powdered materials; also, hard-surfacing and corrosion-resistant alloys, and high-temperature brazing alloys.

Welding Alloy Mfg. Co.
Booth No. 109

Feature: Display of WALCO aluminum welding and brazing alloys, bronze, cable, lenses and cover glass, electrode holders, atmospheric air-acetylene and propane torches and equipment.

Welding Engineer Publications, Inc.
Booth No. 111

Feature: Introduction of new magazine "The Welding Distributor"; also, display of magazines and books on welding, cutting, etc., including "Welding Engineer," "The Welding Encyclopedia," "Gas Welding Manual" and others.

Martin Wells, Inc. **Booth No. 102**

Feature: "Tong-Grip" electrode holders; slip-on insulators, no screws, no rivets. "Tong-Grip" offers cool operating, light, easily repaired, productive, economically maintained holder.

Welsh Manufacturing Co.
Booth No. 632

Display of protective spectacles and lenses, protective goggles, face shields, welding helmets and hand shields, safety hats and various types of protective paint and dust masks.

Weltronic Company
Booth Nos. 309 & 311

Feature: "Digitronic" three-phase frequency converter spot welder control using cold-cathode type counting tubes. Also, 3 hp electronic adjustable motor drive.

Westinghouse Electric Corp.
Booth Nos. 116, 120, 213, 217, 221

Feature: New addition to Westinghouse line—the RST—an ac-dc machine with a complete range of high-frequency equipment. Also, complete display of industrial and utility welders; several new electrodes.

Wheelabrator Corp. **Booth No. 426**

Display of airless abrasive blast cleaning equipment for cleaning and descaling weldments and preparing them for painting and other coatings. Process also used for descaling hot-rolled steel sheet or strip.

Worcester Taper Pin Co.
Booth No. 430

Principal attraction: Introduction of Browning oxy-gasoline cutting torch, featuring safety, speed, quality of cut and fuel economy.

Worthington Corp.
Booth Nos. 100 & 207

Feature: Display of a double AA model turning rolls with idler; model 10P positioner; model 160 positioner with a truck mixer drum; model D power roll; and model 1P table positioner.

●

A number of other organizations will also participate in the 1957 Welding Show. Unfortunately, however, the details of their exhibits were not available at the time that the preceding presentation was prepared and processed for publication.

The name of these companies are as follows:

Acorn Iron and Supply Co., Booth No. 606
Ames Spot Welder Co., Inc., Booth Nos. 140 & 141
Arcair Company, Booth Nos. 153 & 155
Electrons, Inc., Booth No. 254
Gas Arc Supply, Booth No. 604
Glendale Optical Co. Inc., Booth No. 139
Goss Gas, Inc. Booth No. 157
Mitchell Radiation Products Corp., Booth Nos. 610 & 612
Standard Safety Equipment Co., Booth No. 250
Tee Torch Company, Inc., Booth No. 243
Webb Corp., Booth No. 600

More Organizations Join as Supporting Company Members

AWS headquarters has recently received Supporting Company Member Enrollment applications from the following organizations:

Cayuga Machine & Fabricating Co., Inc., 200 West Gould Ave., Depew, N. Y.

Fabriform Metal Products, 7720 Maie Ave., Los Angeles 1, Calif.

Wiesner-Rapp Co., Inc., 1600 Seneca St., Buffalo, N. Y.

These enrollments became effective on Feb. 1, 1957.

Long Beach (Calif.) Section Educational Activities Growing

Four years ago, the Long Beach Section began its educational activities by appropriating a sum of money to be used (1) for the purchase of three very fine trophies and (2) as cash prizes. The trophies are awarded annually, on a perpetual basis, to the junior college whose student has shown the greatest proficiency in the art of welding. The student receives a small cash sum and a one-year membership, class C, in the AWS.

Frank Pope, chairman of the Long Beach Section, reports that the trophies are awarded on the following basis: an annual examination is drawn up by the Awards (EAC) chairman and a committee of his selection; this examination is divided into three parts, each of which constitutes a division, and each winning one of the three awards. These break down as follows: excellence in the art of gas welding and cutting; excellence in the art of arc welding; and the over-all trophy which embodies the complete science. The student must lay out, cut and, then, on a three-part section, must braze weld, arc weld and gas weld a completed pipe section. Last year it was a 90-deg, three-part L (ell) joined to a cast-iron plate.

Each year the work has improved, and each participating college now feels that the trophy is a stimulus, and a highly needed recognition, of the part that the technical trades division plays in the educational life of the school. The plan, in general, has been very well received by both school officials and students.

The Long Beach Section is now in its fourth season of this presentation. It aims strictly at the practical side, preferring this direct method as a beginning. The Section maintains the right, as donor of the trophies, to adjust the examination as it sees fit. With the passing of a few more years, the examination is expected to become both a practical and theoretical test.

In another plan tried by the Section, certain individuals or groups have acted as sponsors by paying the dues and the dinner for undergraduates recommended to them by a local instructor. This plan produced a surprising number of sponsors, but not enough students. Due to the area covered, and distance involved, coupled with the age of the average student, it was decided to abandon this method of educational activity. An interesting sidelight to this activity, however, was the fact that one of the boys who displayed a great deal of interest and companionship with his sponsor, went on to win the annual trophy and was placed in a full time welding job right after graduation.

Another interesting outcome of the trial sponsoring system has been the fact that several students have already become members of the Section. These students pay their own dues and are in regular attendance at the Section's technical meetings; this number grows slowly, but steadily.

EAC DOINGS

The Need for Welder Training

by H. A. Sosnin

If the number of people who could read were very limited, the works of Shakespeare would have little impact on our culture. If the literate percentage of the world's population were low, millions spent on advertising and promotion would still not sell many copies of "Macbeth" or "Mid-Summer Night's Dream." Literature has value only to those who can read.

Just as literature benefits no one until it is read, so welding techniques benefit no one until they are applied. The wider the application, the greater the benefit. Men must know how to weld in order to improve their economy by welding, just as men must know how to read in order to improve their minds by reading.

Development of processes and procedures in welding is of value to the engineering world comparable to the value of Shakespeare's writing to the literary world. It is valuable to the extent to which it can be put to use. The use of all the welding processes and techniques is limited by a shortage of skilled operators. This has been true since the start of modern welding, at the turn of the century. The demand for skilled welders has been greater than the supply since that time.

There may be those who doubt the validity of the preceding statement, and if there are, let them survey the field. Talk to structural designers and find that there are many who would like to design more welded structural steel, but don't because they are met by objections from builders who "can't get enough good welders." There are mechanical engineers who would like to design more welded piping but do not, for the same reason. At least five times as much pipe would be welded as is now welded, if there were enough skilled welders available.

Air conditioning contractors need welders for duct work. Roofing contractors need welders. Even lathers and plasterers need welders today for hung ceilings and wire lathe.

The construction trades are not alone in this shortage. The use of metal fabrication increases every day. Not only automotive shops and appliance manufacturers, but those who make furniture, fans and fences, toys, tanks and trash cans, need workers skilled in the welding arts.

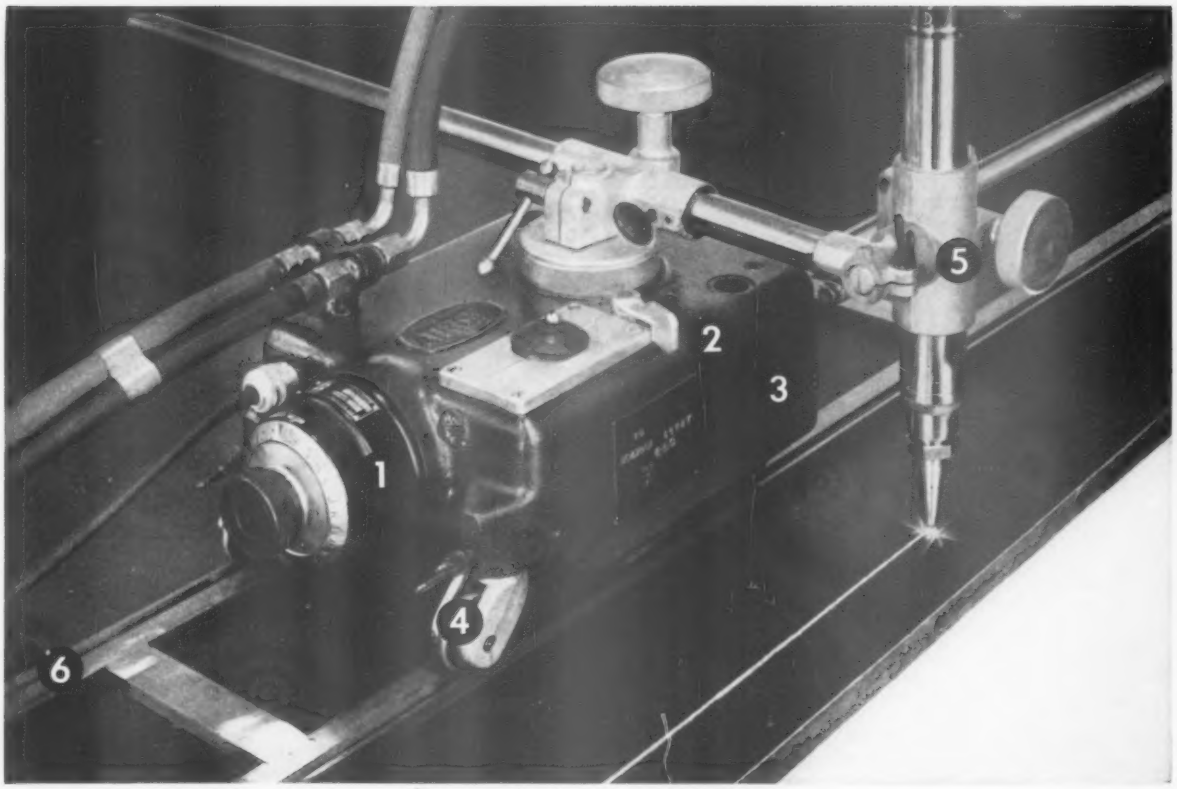
The uses of welding are myriad and the possible sale of welding equipment and materials is practically unlimited, except as affected by "the shortage of welders."

Over a period of many years, the AMERICAN WELDING SOCIETY has led the way in research and development in the *science* of welding. There is now a real need to do as much for the *art* of welding. Design of a structure or pressure vessel is of first importance, but production is essential. A structure or a vessel does not contribute anything to the economy until it is built and in service. This building requires men skilled in the art of welding. It usually requires more man-hours than the design.

Today, the AMERICAN WELDING SOCIETY is attempting to be of assistance to all phases of the welding industry. In particular, the Educational Activities Committee is trying to aid the development of students of all rank and degree in the art and the science of welding. Both are necessary.

The members of the SOCIETY can well serve themselves, the SOCIETY and the Community by aiding the development of the welding skills and arts without which the welding sciences cannot be put to practical use.

H. A. Sosnin, Chairman, Subcommittee on Extension Training and Apprentice Training, AWS Educational Activities Committee; associated with Tube Turns, Inc., Louisville, Ky.



Quality in Details! these factors make the Airco #10 Radiagraph your best buy

The #10 Radiagraph is a portable (43 lb) gas cutting machine designed to cut metals up to 6" thickness. It will cut straight lines of any length, circles from 3" to 85" diameter, arcs up to a radius of 42½" – all with square or beveled edges. Designed to provide the greatest degree of cutting accuracy and convenience of operation, the husky overall construction of the #10 has made it an indispensable tool wherever steel is to be cut to size for fabrication. Here are a few of the *quality details* that don't meet the eye:

1. *Governor Control Variable Speed Motor* puts the entire speed range (4 to 50 ipm) at operator's fingertips. An indicator showing all speed settings is provided. Speed can be increased or decreased while cutting is in progress... speed is not affected by load or voltage changes.

2. *Clutch Lever* allows the machine to be rolled freely in either direction. This feature is a time-saver when aligning the machine with work.

3. *Drive Shaft* (under housing) runs on replaceable needle bearings which reduce friction to a minimum and affords a maximum of free motion.

4. *Caster Wheels* run in a machined groove in track for greater machine stability and more accurate cutting.

5. *Torch Holder Assembly* is made of brass forgings which withstand more abuse than castings and have greater corrosion resistance than iron or steel.

6. *Track* is cold rolled steel with two machined grooves in which wheels travel, and has track sections with tongue and grooved joints for correct alignment when multiple lengths are used for progressive cutting.

Airco oxyacetylene shape cutting machines include the Airco Camograph, Monograph, Duograph, Oxygraph and Travograph. Write today for literature.

welding
AT THE FRONTIERS OF PROGRESS YOU'LL FIND...

VISIT OUR BOOTH 334 — WELDING SHOW
APRIL 9-11, 1957 · PHILADELPHIA, PA.

AIRCO®
Offices and dealers in most principal cities

AIR REDUCTION SALES COMPANY
A division of Air Reduction Company, Incorporated
150 East 42nd Street, New York 17, N. Y.

On the west coast — Air Reduction Pacific Company
Internationally — Airco Company International
In Cuba — Cuban Air Products Corporation
In Canada — Air Reduction Canada Limited

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide — gaseous, liquid, solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl acetate, alcohols, and other synthetic resins.

AMERICAN WELDING SOCIETY
WESTERN METAL CONGRESS
Ambassador Hotel, Los Angeles, Calif.
MARCH 25–29, 1957

MONDAY, MARCH 25

NOON—KICK-OFF LUNCHEON. "The Role of Welding in Industrial Advancement," John J. Chyle, National President, AMERICAN WELDING SOCIETY, and Director of Research, A. O. Smith Corp., Milwaukee, Wis.

AFTERNOON SESSION. *Chairman:* Milt Sims, Absco, Inc.

2:30 "Welding Codes—Stimulant or Stumbling Block," T. B. Jefferson, Editor and Publisher, *Welding Engineer*, Chicago, Ill.

TUESDAY, MARCH 26

Aircraft & Rocketry

MORNING SESSION. *Chairman:* Mario Ochicano, Lockheed Aircraft Co. *Co-Chairman:* George Foster, Air Reduction Pacific Co. *Supervisor:* Harlan Meredith, Airline Welding & Engineering Co.

9:00 "Recent Developments in Magnetic-Force Welding," Jack Funk, Development Engineer, Precision Welder & Flexopress Corp., Cincinnati, Ohio.

10:00 "Inert-Gas Consumable-Electrode Welding of Aluminum Alloys in Liquid Aircraft Rocket," Walter S. Tenner, Welding Engineer, U. S. Naval Ordnance Test Station, Pasadena, Calif., and Paul T. Barnes, Project Engineer on "LAR," U. S. Naval Test Station, China Lake, Calif.

11:00 "Resistance Welding Titanium Alloy Structures," Wm. R. Gain, General Supervisor, Boeing Airplane Co., Seattle, Wash., and Howard E. Woodward, Research Engineer, Boeing Airplane Co., Seattle.

AFTERNOON SESSION. *Chairman:* Leo West, Douglas Aircraft Co., Inc., Long Beach. *Co-Chairman:* Howard Eubank, Convair, Pomona Division. *Supervisor:* Bruce Baird, North American Aviation, Downey, Calif.

2:00 "Resistance Welding Controls Using Counter Tubes," J. J. Riley, Chief Electrical Engineer, Taylor-Winfield Corp., Warren, Ohio.

2:45 "Stress Corrosion of Titanium Weldments," Wm. S. Arter, Research Engineer, North American Aviation, Downey, Calif.

3:30 "Vacuum Brazing of Sandwich Structures," G. Jewett Crites, Independent Engineering Consultant, El Segundo, Calif.

WEDNESDAY, MARCH 27

MORNING SESSION. *Chairman:* Russell Graves, The Fluor Corp. *Co-Chairman:* Francis Redman, Southwestern Engineering Co. *Supervisor for the Day:* M. K. McEniry, National Cylinder Gas Co.

9:00 "Welding for Nuclear Pumping Applications," Frank R. Drahos, Chief Metallurgist, Byron Jackson Co., Los Angeles, Calif.

9:45 "Ultra High-Strength Weld Metal for Aircraft Fabrication," D. C. Smith, Chief Metallurgist, Harnischfeger Corp., Milwaukee, Wis.

10:30 "An Evaluation of Filler Materials for Use on High-Strength, Low-Alloy Steels," Frank G. Harkins, Chief Process Engineer, Solar Aircraft Co., San Diego, Calif.

11:15 "Weld Roll Planishing—The Weld Helper," Harlan L. Meredith, Vice-President and Engineer, Airline Welding & Engineering, Hawthorne, Calif.

AFTERNOON SESSION. *Chairman:* Herb B. Evans, Associated Piping & Engineering Co. *Co-Chairman:* Jack L. Taylor, Superior Tank & Construction Co.

2:00 "Today's Field Welding of Pressure Piping in the Refinery, Power and Pipeline Industries," A. M. Croswell, Senior Welding Engineer, Bechtel Corp., San Francisco, Calif.

2:45 "Inert-Gas-Shielded Arc Welding of the Aluminum Alloys," Paul Dickerson, Process Development Engineer, Aluminum Company of America, New Kensington, Pa.

3:30 "Weldability of High-Temperature Alloys," R. P. Culbertson, Head of Process Development Section, Haynes Stellite Co., Kokomo, Ind.

THURSDAY, MARCH 28

MORNING SESSION. *Chairman:* Leo Gatzek, Bendix Aviation Corp. *Co-Chairman:* Robt. E. Jones, Superweld Corp. *Supervisor for the Day:* Frank Soady, Air Reduction Pacific Co.

9:00 "Welding of Light Gage Materials," T. McElrath, Development Engineer, Linde Air Products Co., Newark, N. J.

9:45 "Evaluation of Hard-Facing Materials," Dave Rankin, Owner, Rankin Manufacturing Co., Alhambra, Calif.

10:30 "A New CO_2 Welding Process," A. F. Chouinard, Research & Development Engineer, and R. T. Monroe, Manager of Technical Sales, National Cylinder Gas Co., Chicago, Ill.

11:15 "Tool and Die Welding with Inert-Gas, Metallic-Arc and Atomic-Hydrogen Process," Patrick S. Doyen, General Manager, Welding Equipment & Supply Co., Detroit, Mich.

AFTERNOON SESSION. *Chairman:* Al B. Bennett, Solar Aircraft Co. *Co-Chairman:* Jack Porter, Aerojet General Corp.

2:00 "High-Temperature Atmosphere Silver Brazing," A. M. Setapen, Manager of Engineering, Handy & Harmon Co., New York, N. Y.

2:45 "Selection of the Proper Inert-Gas-Shielded Arc-Welding Process," C. B. Robinson, Head of Process Development Section, Air Reduction Pacific Co., San Francisco, Calif.

3:30 "The Inert-Gas Welding of Nickel and High-Nickel Alloys," K. M. Spicer, Asst. Supervisor, Mechanical Engineering Section, International Nickel Co., New York City, N. Y.

FRIDAY, MARCH 29

MORNING SESSION. *Chairman:* Art Williams, Consolidated Western Steel. *Co-Chairman:* Chas. Zwissler, Kaiser Steel Corp., Fabrication Division. *Supervisor:* Cam Perry, Absco, Inc.

9:30 "The Use of Iron Powder in Arc Welding Electrodes," Richard K. Lee, Vice-President and Manager of Product Development, Alloy Rods Co., York, Pa.

10:15 "Study of Causes of Weld Metal Cracking in High Strength Steel," Glen Faulkner, Asst. Chief of Welding Division, Battelle Memorial Institute, Columbus, Ohio.

11:00 "Constant Voltage Type Welders and Their Applications," L. P. Henderson, Welding Engineer, M & T Welding Products Corp., Oakland, Calif.

HOW THREE PHASE RESISTANCE WELDING IS USED TO FABRICATE STRUCTURAL STEEL

Production proves Sciaky techniques of resistance welding provide the consistently safe welds necessary for assembling primary structures.

For over 20 years resistance welding has been used to fabricate metal structures by many European contractors. However, until recently the process has been restricted to relatively light sections.

Structural Steel Fabrication

In Rouen, France, Enterprises Metropolitaines & Coloniales is now successfully resistance welding heavy structural beams into composite strength members.

Figure 1 shows a typical cross section of two "I" beams spot welded together. Figure 2 shows a more elaborate development of the assembly shown in Figure 1. Five "I" beams are welded into one composite strength member.

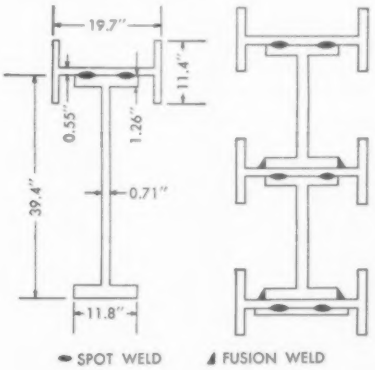


Fig. 1 Fig. 2

A typical beam is almost 69 feet long. It is part of an assembly 131 feet long weighing 45 tons. A total of 182 spot welds in two rows is used to fabricate the structure.

Sequence of Operations

To facilitate production, beam elements to be welded are mounted on an arrangement of two carriages located in front of the welder. One of the carriages is powered and operated by remote control by the single operator (not skilled) who also triggers the weld sequence. Indexing time is 4 seconds.

The welding of the assembly is accomplished in four operations. Operation No. 1 begins in the middle of the column. One row is made to the end and the welder returns to the middle to weld the balance of the row in the other direction. The second row is accomplished in the same manner.

The average time required for each spot weld including indexing is less than 40 seconds. *The entire beam is fabricated in less than two hours including set-up time.*

The Welder

The welder is a Sciaky Patented Three Phase 450 KVA Welder designed to be operated from a cradle or in a suspended position (as shown in the photograph). Power supply is 220 volts. Maximum electrode force is 14 tons. Maximum secondary current is 75,000 amps. Controls are located directly opposite the welder.

The key to successful welding of heavy structural shapes is the Sciaky Patented Three Phase Principle. In addition to its many other advantages it provides the weld quality and consistency essential to primary structure fabrication.

Advantages of Resistance Welding

The use of Sciaky Resistance Welding Techniques results in a substantial saving in material and weight.

It eliminates extra beam size necessary to compensate for the weakening effect of rivet holes. The extra operation and time necessary to drill rivet holes is eliminated. In addition the material and weight contained in rivet heads is eliminated.

Only one worker (not skilled) is needed for the welding operation.

Further Information

More detailed information on this operation is presented in a twelve page illustrated report. Write for your copy, asking for the *"Resistance Welding at Work Special Report on Fabricating Structural Steel."* There is no obligation.

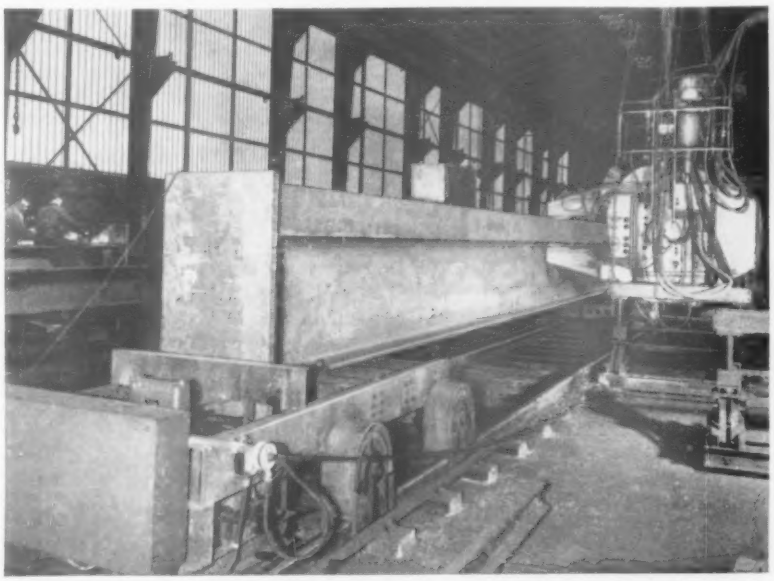


Fig. 3 View of beam riding on powered dolly as welds are being made by the Sciaky Patented Three Phase Welder.

Largest Manufacturers of Resistance Welding Machines in the World

SCIAKY

Sciaky Bros., Inc., 4919 West 67th Street, Chicago 38, Ill., Portsmouth 7-5600

Section News and Events

as reported to Catherine O'Leary

EDUCATION

Albuquerque, N. M.—Some 110 members and guests of the *Albuquerque* Section attended a party on December 15th held at La Placita dining room in "Old Town."

The speaker, E. E. Harrington, was quite interesting and included numerous anecdotes and experiences of his varied career in the education field.

A good time was had by all.

PLANT TOUR

Fort Wayne, Ind.—A plant visit by the members of the *Anthony Wayne* Section to the Specialty Transformer Department, General Electric Co., was held on January 17th.

An address of welcome was given by H. R. Korte, manager of manufacturing engineering. Mr. Korte discussed the various welding processes used in the department and the sequence in which they appeared. He showed slides of various transformers made in the department and a color film on the manufacture of oil burner ignition transformers. The tour covered a number of interesting welding operations including projection welding, flash welding and gas-shielded metal-arc welding.

GUIDED MISSILES

Birmingham, Ala.—The January dinner meeting of the *Birmingham* Section was held on January 8th at Gulas's Restaurant.

An address by Dr. W. R. Lucas, chief of Army Ballistic Missile Agency, Materials Section, covered the four guided missiles developed by the U. S. Army: namely, the Nike 1XSAM-A-7, the Honest John, the Corporal and the Redstone. With the use of slides, film strips and scale models, an excellent explanation of the production facilities, laboratories and development problems of such an installation was covered.

Of special interest to the group were two specific development problems brought out by Dr. Lucas. The first was the inspection of welds and the second, the mitigation of corrosion on the missile proper. In the fabrication of such missiles, all welds are 100% inspected by X-ray. This is a time-consuming process. Attempts are being made to develop a method using supersonic sound techniques for this inspection. The corrosion problem is due primarily to the type of fuels used and the extremely long storage periods that such missiles must be designed to withstand. This results in specific long-range studies to be continuously conducted on the individual components of the missile.

The subject of guided missiles, one of national importance, was well received by the group.

ARC-SPOT WELDING

Boston, Mass.—In spite of the extremely adverse weather conditions, the *Boston* Section had a very interesting and educational meeting on the 14th of January. Approximately 120 enjoyed the usual delicious dinner and then adjourned to the Auditorium to hear Joseph W. Kehoe AWS, manager, Metals Joining Lab., Westinghouse Co., give an illustrated talk on "The Inert-Gas-Shielded Metal-Arc Spot Process." Although the process is not intended to replace resistance spot welding, Mr. Kehoe's interesting talk convinced the majority of those present that it has many applications due to its mobility and low power requirements. The spirited discussion period that followed indicated that the meeting had been well received.

THERMAL CUTTING

Bridgeport, Conn.—The January dinner meeting of the *Bridgeport* Section was held on January 17th at the Fairway Restaurant.

Technical speaker was Ivar Steen AWS, of the Air Reduction Co. Mr. Steen explained the gas-shielded metal-arc cutting process, its advantages and disadvantages, and its future in welding. His talk was accompanied by representative samples which he passed around for close inspection.

INERT-GAS WELDING

Chicago, Ill.—The regular montl ly dinner meeting of the *Chicago* Section was held on January 18th. The din-

(*Continued on page 289*)

ALBUQUERQUE SECTION CELEBRATES WITH PARTY

Part of the happy crowd that attended the December 15th party given by the Albuquerque Section

G.E. TRANSFORMER DEPARTMENT VISITED BY ANTHONY WAYNE SECTION

Members and guests of the Anthony Wayne Section shown during their tour of the G.E. plant on January 17th

SECTION MEETING CALENDAR

APRIL 1

LEHIGH VALLEY Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Walp's Restaurant, Allentown, Pa. "Battle of the Sections": Philadelphia-Susquehanna Valley; York-Central Pa.; and Lehigh Valley.

SAN FRANCISCO Section. Spenger's Fish Grotto, Berkeley, Calif. "Low-Hydrogen Type Iron-Powder Electrodes," Richard K. Lee, Alloy Rods Co.

APRIL 3

SUSQUEHANNA VALLEY Section. Dinner 6:45 P.M. Technical session 8:15 P.M. American Legion, Kingston, Pa. "Gas Welding," A. N. Kugler, Air Reduction Sales Co.

APRIL 5

NORTH CENTRAL OHIO Section. Annual Ladies' Night. Marion Country Club, Marion, Ohio. Dinner 7:00 P.M. Flowers and prize drawing for the ladies. Refreshments and dancing.

PHILADELPHIA Section. Panel discussion: "Automatic Hard Surfacing and Overlay."

APRIL 4

NORTHERN NEW YORK Section. Stanley Club, Pittsfield, Mass. "Magnetic Force Welder," Myron Zucker, Zucker Engineering Co.

APRIL 8

NORTHWEST SECTION. Happy half hour-6:00 P.M. "Fuel Gases Used in Cutting, Heating and Welding Operation," Harold Mendenhall.

APRIL 9

DAYTON Section. Dayton Engineers Club. "Submerged-Arc Welding."

YORK-CENTRAL PENNSYLVANIA Section. Lincoln Woods Inn, York, Pa. Dinner 6:30 P.M. Meeting 7:30 P.M. "Modern Steels and Their Weldability" W. D. Doty, U. S. Steel Corp.

APRIL 10

CLEVELAND Section. Hotel Manger, Cleveland, Ohio. "Welding of Stainless Steel," H. Reid, McKay Co.

APRIL 11

MADISON Section. Eagles Club, Madison, Wis. Panel discussion on Manipulation Techniques of Arc Welding. *Moderator:* F. Theiler.

APRIL 12

COLUMBUS Section. Columbus, Ohio. "Ultrasonic Welding," Byron Jones, Aeroprojects, Inc.

PUGET SOUND Section. Social meeting with ladies invited.

ST. LOUIS Section. Forest Park Hotel. "Control and Correction of Welding," LaMotte Grover, Air Reduction Co.

APRIL 15

ROCHESTER Section. Liederkranz Club, Rochester, N. Y. Dinner 6:30 P.M. Meeting 8:00 P.M. "Principles and Applications of Resistance Welding," Wm. J. Farrell, Sciaky Bros., Inc.

APRIL 16

NEW JERSEY Section. Essex House Hotel, Newark, N. J. Dinner 6:30 P.M. Meeting 8:00 P.M. "Automatic Submerged-Arc Welding Operations." Representative of Hobart Bros., Inc.

NORTHWESTERN PA. Section. Erie, Pa. "Control and Correction of Welding Distortion," LaMotte Grover, Air Reduction Co.

APRIL 18

KANSAS CITY Section. Dinner meeting. Golden Ox (Livestock Exchange Bldg.) Kansas City, Mo. "Inspection Techniques for Better Welding," Lew Gilbert, Industry and Welding.

MICHIANA Section. South Bend, Ind. "Welding Austenitic Stainless Steels," D. W. McDowell, International Nickel Co.

SHREVEPORT Section. Dinner 7:00 P.M. Meeting 8:00 P.M. Colonial Room, Captain Shreve Hotel, Shreveport, La. "Gas-Shielded Constricted Arc Cutting of Aluminum and Other Alloys," R. P. Wilson, Linde Air Products Co.

APRIL 19

DETROIT Section. Dinner 6:15 P.M. Meeting 8:00 P.M. Engineering Society of Detroit. Quiz the Experts.

APRIL 22

SAN FRANCISCO Section. "Inert-Gas Welding," J. E. Dato, Linde Air Products Co.

APRIL 25

MARYLAND Section. Engineers Club, 6 W. Fayette St., Baltimore, Md. "Hard Surfacing," Harry V. Kough, Coast Metals.

NIAGARA FRONTIER Section. Mann's Club, 3405 Bailey Ave., Niagara Falls, N. Y. "The Evaluation of Arc-Welding Electrodes," Mike H. Robinson.

APRIL 26

CHICAGO Section. Dinner 6:15 P.M. Milner's Restaurant. Meeting 7:30 P.M. People's Gas Auditorium, 122 S. Michigan Ave., Chicago. "Inspection Technique for Welding," L. Gilbert, Industry and Welding.

INDIANA Section. Antlers Hotel, Indianapolis, Ind. Quiz the Experts.

MILWAUKEE Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Ambassador Hotel, Milwaukee, Wis. "Welding of High-Tensile Alloys," D. C. Smith, Harnischfeger Corp.

Editor's Note: Notices for June 1957 meetings must reach Journal office prior to April 1, so that they may be published in May Calendar. Give full information concerning time, place, topic and speaker for each meeting.

Independent Metal Products welds tank trailers from alloy 5154 at speeds up to 80 ipm.

They're welding aluminum tank trailers at speeds up to 80" per minute!

Alcoa's 5154 alloy is going over big with trailer builders such as Independent Metal Products Division of Fruehauf Trailer Company.

It has good forming characteristics combined with great strength and ductility in welded sections. Moreover, it can be welded at speeds up to 80 inches per minute by the inert-gas shielded arc consumable-electrode welding method.

Production welds of alloy 5154, using parent alloy for filler wire, have excellent ductility . . . 39% elongation in the weld metal when a joint is bent until it fails.

With these improvements, aluminum tank trucks make substantial weight savings—savings that are turned into extra payload profit. At the same time, tank shell strength is increased . . . and accident damage is reduced. Aluminum tanks absorb substantial distortion without cracking or weld failure. One large tank truck operator says:

"In actual operating conditions—5,175,000 miles—our aluminum tanks have proved to be safer than tanks constructed of steel, particularly in resistance to rupture on overturn."

Alcoa® is headquarters for fresh, exciting ideas on how to weld, braze or solder aluminum. Get in touch with us. Where? See information at right.

* * *

Learn how easy it is to weld, braze or solder aluminum. Write for free, informative books and films. Aluminum Company of America, 1741-C Alcoa Building, Pittsburgh 19, Pa.

THE ALCOA HOUR
TELEVISION'S FINEST LIVE DRAMA
ALTERNATE SUNDAY EVENINGS

WE CHOSE ALCOA ALUMINUM

Your Guide to the Best in Aluminum Value

Visit the Alcoa Booth at the Welding Show — Philadelphia, April 8-12

Want technical help in welding, brazing or soldering aluminum? Contact your Alcoa sales office, listed under "Aluminum" in the Yellow Pages of your phone book.

For immediate delivery of Alcoa welding products, call your Alcoa outlet listed below. He carries a complete range of alloys and sizes.

ALABAMA
Birmingham
Hinkle Supply Co.
CALIFORNIA
Los Angeles
Pacific Metals Company, Ltd.
San Francisco
Pacific Metals Company, Ltd.
COLORADO
Denver
Metal Goods Corp.
CONNECTICUT
Milford
Edgcomb Steel of New England, Incorporated
FLORIDA
Jacksonville
J. M. Tull Metal & Supply Co., Inc.
Miami
J. M. Tull Metal & Supply Co., Inc.
Tampa
J. M. Tull Metal & Supply Co., Inc.
GEORGIA
Atlanta
J. M. Tull Metal & Supply Co., Inc.
Southern Oxygen Co.
IDAHO
Boise
Pacific Metal Co.
ILLINOIS
Chicago
Machinery & Welder Corp.
Steel Sales Corp.
Moline
Machinery & Welder Corp.
KENTUCKY
Louisville
Williams and Co., Inc.
LOUISIANA
New Orleans
Metal Goods Corp.
MARYLAND
Baltimore
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
MASSACHUSETTS
Cambridge
Whitehead Metal Products Co., Inc.
MISSOURI
Kansas City
Metal Goods Corp.
St. Louis
Metal Goods Corp.
NEW HAMPSHIRE
Nashua
Edgcomb Steel of New England, Inc.
NEW JERSEY
Camden
Southern Oxygen Co.
Harrison
Whitehead Metal Products Co., Inc.
NEW YORK
Albany
Eastern Metals Warehouse, Inc.
Buffalo
Whitehead Metal Products Co., Inc.
New York
Whitehead Metal Products Co., Inc.
Syracuse
Brace-Mueller-Huntley, Inc.
Whitehead Metal Products Co., Inc.
NORTH CAROLINA
Charlotte
Southern Oxygen Co.
Greensboro
Southern Oxygen Co.
OHIO
Cincinnati
Williams and Co., Inc.
Cleveland
Nottingham Steel & Aluminum Co.
Williams and Co., Inc.
Columbus
Williams and Co., Inc.
Toledo
Williams and Co., Inc.
OKLAHOMA
Tulsa
Metal Goods Corp.
OREGON
Portland
Pacific Metal Co.
PENNSYLVANIA
Philadelphia
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
Pittsburgh
Williams and Co., Inc.
York
Southern Oxygen Co.
TENNESSEE
Kingsport
Southern Oxygen Co.
TEXAS
Dallas
Metal Goods Corp.
Houston
Metal Goods Corp.
UTAH
Salt Lake City
Pacific Metals Company, Ltd.
VIRGINIA
Norfolk
Southern Oxygen Co.
Richmond
Southern Oxygen Co.
WASHINGTON
Seattle
Pacific Metal Co.
WASHINGTON, D. C.
Southern Oxygen Co.
WISCONSIN
Milwaukee
Machinery & Welder Corp.

ner, which 45 attended, was held at Milner's Restaurant. The meeting, with 117 present, was held in the Auditorium of the Peoples Gas Light & Coke Co. Two pre-meeting films were shown by Association Films, Inc. They were "Goggles and Gauntlets" and "The King Who Came to Breakfast." Both were well received by the audience.

Featured speaker was Gilbert R. Rothschild AWS, of the Air Reduction Co. Mr. Rothschild's talk covered the welding conditions obtained using various types of shielding inert gases and also the various results obtained using d-c straight and reverse polarity.

The talk was accompanied by slides and a short movie on metal transfer in inert metal-arc welding. Mr. Rothschild also covered the theory of the various factors which are responsible for metal transfer in the arc.

HIGH-TEMPERATURE BRAZING

Cincinnati, Ohio—Technical speaker at the January 22nd meeting of the *Cincinnati* Section was George S. Hoppin, III AWS, of the Flight Propulsion Laboratory Department, AGT, General Electric Co. The subject of Mr. Hoppin's talk was "High-Temperature Brazing of Jet-Engine Materials."

Mr. Hoppin's talk covered the new family of brazing alloys which have appeared since 1950 for the brazing of components for service and temperatures up to 2000° F. He discussed the initial development of the NiCrSiB hard-surfacing alloy as a high-temperature brazing material by Boam and Peaslee in 1950. There are three important classes of high-temperature brazing materials: (1) NiSiCrB alloys; (2) NiCrSi; (3) NiSiB.

All these materials have shown excellent strength at high temperature and have excellent oxidation resistance. Of considerable significance is the increase in the melting temperature of the brazing material by diffusion of boron into the base materials. Due to their high room-temperature hardness and brittleness, these high-temperature materials are primarily available as powders. However, they may also be secured plastically bonded in strips, wire or pre-forms.

In processing, furnace atmospheres are very critical. In most cases, a dry hydrogen atmosphere of −40 or better is preferred. Surfaces must be absolutely clean prior to brazing. A number of variables affecting processing are as follows: (1) nature of brazing atmosphere; (2) cleanliness

CLEVELAND SECTION HOLDS EXECUTIVES' NIGHT

Part of the large crowd in attendance at the January 9th meeting of the Cleveland Section

Shown at the Speakers' Table are I. B. Hexter, president of Industrial Publishing Co., guest speaker L. B. Seltzer, who spoke on the St. Lawrence Seaway and A. G. Portz, Section chairman

James Dawson, second guest speaker, is shown at left; Bill Mayor, Section vice-chairman, center; and Tom Elder, Section secretary, right. Mr. Dawson discussed future business conditions.

IOWA SECTION HOLDS CHRISTMAS PARTY

Two happy scenes from the Christmas dinner dance held by the Iowa Section on December 18th

of base material; (3) composition of the base material; (4) composition of the brazing alloy; (5) purity of the base alloy; (6) composition of the brazing alloy binder; (7) brazing temperature.

One of the critical problems has been the erosion effect of the brazing alloy on a thin sheet material. Present applications have been used primarily in the aircraft, missile, rocket, jet engine, and nuclear energy fields. Brazed honeycomb aircraft structures are now being used in our latest supersonic planes. High-temperature brazing is still in its infancy. The future should see ever increasing applications of the process and improving materials. The most significant process improvement to be expected will be the commercialization of vacuum brazing which is still in the laboratory stage.

EXECUTIVES' NIGHT

Cleveland, Ohio—Two speakers were featured at the annual "Executives' Night" dinner meeting of the *Cleveland* Section held on January 9th in the Ballroom in the Manger Hotel.

The first speaker, L. B. Seltzer, editor of the Cleveland *Press*, discussed the future of Cleveland, and especially what effect on economy the St. Lawrence Seaway will have. It is his opinion that Northeastern Ohio will grow faster because of what they have to offer to industry: trained men, close vicinity to raw materials, the Great Lakes, the Freeway, railroad center, steel mills, and other advantages.

The second speaker was James N. Dawson, vice-president and economist for the National City Bank of Cleveland. Mr. Dawson stated that the outlook for business in 1957 is very good, especially up until May of this year. The graphs show an upward trend to good business.

Approximately 350 were present at this very enlightening meeting.

OXYACETYLENE CUTTING

Dallas, Tex.—The first meeting of the *Dallas* Section for the new year was held on January 16th at the Delta Restaurant, where an excellent meal was served.

R. L. Deily AWS, technical consultant on metallurgy from the New York office of the Air Reduction Co., gave a most interesting talk on "Oxyacetylene Cutting." His talk was illustrated by a 25-minute color movie and slides.

WELDING PROBLEMS

Dayton, Ohio—Ted Jefferson AWS, editor and publisher of *Welding Engineer* and *Welding Encyclopedia*, addressed 58 members and guests of the *Dayton* Section at a dinner meeting held on January 8th at the Dayton Engineers Club.

Mr. Jefferson discussed some of the problems confronting welding, the best approach to overcome these problems and what might be expected in the future in the welding industry.

WELDING AND BRAZING ALUMINUM

Dayton, Ohio—The December meeting of the *Dayton* Section was held on December 11th at the Dayton Engineers Club.

Guest speakers were Paul B. Dickerson AWS, and William S. Hamilton AWS, engineers of the Joining Section of Alcoa Brazing Development Laboratories. Mr. Dickerson's subject "Recent Advances in Aluminum Welding and Cutting" covered a description of tungsten-arc and consumable-electrode welding. Mr. Hamilton's subject "Brazing Aluminum Alloys" concerned the brazeable alloys, brazing alloys, fluxes, process and techniques.

The speakers used lantern slides to further illustrate their topics, and finished their presentation with their film on "Aluminum Brazing," detailing the difference in the three methods of brazing of aluminum: torch, furnace and dips.

STAG PARTY

Detroit, Mich.—The annual Stag Party of the *Detroit* Section was held on December 14th at the American Legion Hall. Nearly 500 members and guests attended and enjoyed a good time with the opportunity for all to visit with the many members of the local welding fraternity. Roy Clark AWS, and Ernie Hoisington AWS, of Uniflex Cable Division welcomed the group. Refreshments were in keeping with the evening and "The Singing School Teachers" created a real party atmosphere.

SPEAK AT JOLIET-AURORA-KANKAKEE DIVISION

Principal speakers at the Dec. 20, 1956, meeting of the Joliet-Aurora-Kankakee Division of the Chicago Section were Ted Jefferson (left) and John Matasovic (right). Mr. Jefferson spoke on the future growth of welding; Mr. Matasovic showed color slides taken during recent trip in Russia

NUCLEAR PIPE WELDING

Glastonbury, Conn.—The January 8th meeting of the *Hartford* Section was held at the Villa Maria Inn in Glastonbury, Conn.

A cocktail hour was held prior to a 7.00 P.M. dinner. Chairman Morton Kenyon AWS, opened the meeting at 8.00 P.M.

The speaker for the evening was George W. Kirkley AWS, design welding engineer for the Electric Boat Division of the General Dynamics Corp., builders of the world's first nuclear powered propulsion system, the submarine *Nautilus*.

Mr. Kirkley spoke on the latest application for consumable-insert welding in the field of nuclear piping systems. Consumable-insert welding is a method of root pass welding without the use of a conventional backing ring. Even though all welding is done from the outside, the resulting internal weld surface is smooth and free of crevices and potential crack starters, both of which may occur with backing-ring welds. Consumable inserts are preplaced between pipe ends and are completely consumed by a tungsten arc forming a weld nugget of constant cross section at the bottom of the weld groove. Also discussed were unique applications for plate and pressure vessel welding. One of the most recent developments by this revolutionary process is the elimination of some 2000 socket-type welds in the reactor piping of an atomic submarine. All pipe sizes 1 in. and below were previously socket welded. Consumable inserts eliminate the troublesome crevices between pipe ends and the bottom of the socket and replaces it with a smooth crevice-free internal weld surface. In a conventional socket-welded system, straight runs of pipe are welded to each end of a coupling. Consumable-insert welding eliminates one of these welds and also the coupling itself.

Highlight of the talk was the showing of a recently released color movie on this method of welding. The film was prepared by Electric Boat Division and the Arcos Corp. and, by the use of high-speed photography, shows the actual melting of the insert and the resulting weld puddle which is caused by the combined phenomena of surface tension and capillary action.

DESIGN OF WELDED JOINTS

Houston, Tex.—Some 100 members and guests of the *Houston* Section were present at the January 23rd dinner meeting held at the Ben Milam Hotel.

A. N. Kugler AWS, chief welding engineer for Air Reduction Sales Co., was the guest speaker. Mr. Kugler gave a very interesting talk with chalk-board discussion on the design of joints for welded fabrication. The talk covered the joining of light material as well as heavy sections. The consideration of static and dynamic loading and the importance of considering fatigue stress was also covered.

Mr. Kugler closed his talk with a short discussion on the design of joints for brazing. A very interesting question and answer session followed.

CHRISTMAS PARTY

Des Moines, Iowa—On Dec. 18, 1956, a Christmas party (dinner and dance) was given by the *Iowa* Section at the Des Moines Golf and Country Club.

AIRCO

WELDING and BRAZING *Hints*

PROBLEM:

To weld cast iron

SOLUTION:

Airco #9 Cast Iron (square). This is a high quality, grey cast iron welding rod commonly used for oxyacetylene welding of cast iron. It assures easy weldability and will produce soft machinable deposits when used with correct pre- and post-heating procedures.

Airco #10 Moly-Cast Iron (square). Deposits obtained with this rod are stronger than those from standard cast iron rods. Recommended for welding alloy cast iron and for building-up worn areas on diesel engine cylinder heads. This rod may be used for welding alloy cast iron of the same or different analysis providing the base metal does not contain ingredients to produce some special characteristic such as corrosion resistance.

Atlas Cast Iron Welding Flux. This flux has a lower specific gravity than cast iron, thus floats out the oxides and impurities to assure sound cast iron weld metal. To expedite the job, sprinkle some of this flux over the joint and the molten puddle.

Send for this free catalog!
You'll find here the finest rods and fluxes for joining both ferrous and non-ferrous metals. Write Airco at address below.

Request Catalog 9-13WJ

AIRCO

AIR REDUCTION

New York 17, N. Y.

Offices and dealers in most principal cities

On the west coast—
Air Reduction Pacific Company
Internationally—
Airco Company International
In Cuba—
Cuban Air Products Corporation
In Canada—
Air Reduction Canada Limited

Transport tank begins to take shape, as butt joints are welded to form outer shell. Heil Company is one of the top producers of aluminum transport tanks.

Switch to Fillerarc* equipment boosts

PRODUCTION RISE ATTRIBUTED TO FASTER WELDING, FEWER REJECTS

Building aluminum transport tanks that must withstand pressures of 34,000 pounds per square inch requires welds that are near-perfect . . . leakproof.

At the Heil Company, Milwaukee, Wisconsin strict tests show that more tanks welded with General Electric automatic and semi-automatic welders are leak-free than those welded with any other equipment they have used or tested.

Rejects have been cut so much since the switchover to General Electric Fillerarc equipment that production has jumped 35%.

Increased speed of welding is also helping to boost production at Heil. The automatic current regulation and constant arc length features of the equipment enable weldors to set the generators once and then forget about them . . . even if they change wire speed in the middle of a job.

This saves the time previously spent crawling in and out of the tank bodies to change settings.

WIRE PULLING FEATURE REDUCES JAMMING

Weldors are enthusiastic over the fact that the Fillerarc gun pulls the wire to the work instead of pushing it. Using fine $\frac{1}{16}$" aluminum wire, Heil had experienced considerable kinking with previous equipment. According to Harold Woda, weldor-fitter, "We couldn't weld an hour straight without it jamming up. Now, using the Fillerarc gun, the wire never jams," he says.

Bill Dyble, supervisor of welding engineering and research for Heil, is pleased with the constant arc length feature of Fillerarc welders. "Constant arc voltage prevents burnback," he says. "Before switching to Fillerarc welders some of our operators spent as much as two hours a day overhauling their torches."

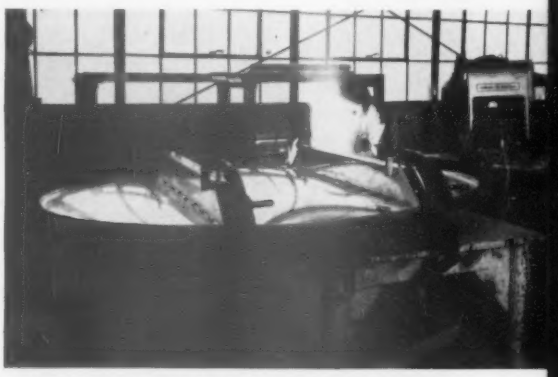
*Reg. trademark of General Electric

GENERAL ELECTRIC

FIRST STEP IN TANK PRODUCTION is joining sheets of 5/32" thick aluminum alloy, type 5154. Automatic Fillerarc welding is used here. Inset shows sample of weld obtained.

COMPARTMENT SECTIONS SECURED with semi-automatic Fillerarc welders. Wire drive, argon gas cylinder are on cart for easy portability.

WELDOR ADJUSTS WIRE SPEED with remote-control unit . . . no need to crawl out of tank. Automatic current and arc-length features of equipment take care of the rest.



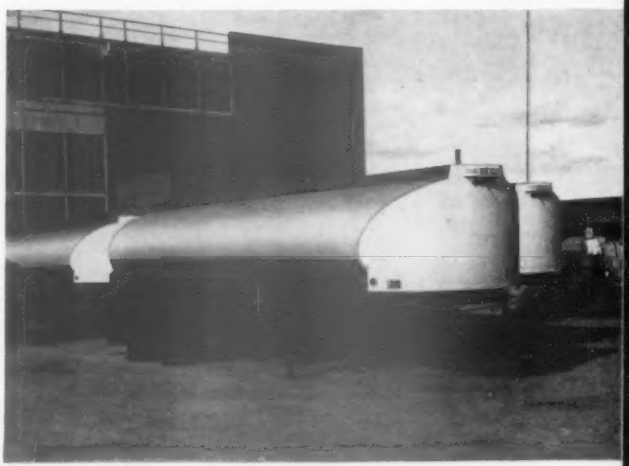
COMPARTMENT SEPARATORS ARE WELDED on special holding fixture. Wire pulling Fillerarc gun reduces jamming, cuts maintenance time.

tank production 35% at Heil Company

Fillerarc welding is General Electric's consumable-electrode, gas-shielded process for either semi-automatic or automatic welding. Now, using carbon dioxide gas as the shielding agent, the Fillerarc system is ideal for mild steel applications. It is fast, economical, clean (no messy flux to bother with), AND, the welds obtained are sound, weld after weld.

For a demonstration of the Fillerarc process, contact your nearby General Electric Welding Distributor. He is listed in the yellow pages of the telephone book. Or, write for more information to Section 713-8, General Electric Company, Schenectady, New York.

Be sure and see the General Electric display at the American Welding Society show, April 9–11, Convention Hall, Philadelphia, Pennsylvania, booth No. 322.



FINISHED PRODUCT—an aluminum petroleum tank, fabricated with Fillerarc welding equipment. Capacities of these tanks run from 3,000 to 9,000 gallons.

Forty-five couples enjoyed a delicious buffet dinner and dance.

FUTURE OF WELDING

Joliet, Ill.—The third meeting of the newly formed group known as the *Joliet-Aurora-Kankakee Division* of the *Chicago* Section was held on Dec. 20, 1956, in Tony's Restaurant near Joliet. Members' wives were invited to this meeting.

Ted Jefferson, AWS, editor and publisher of *Welding Engineer*, and John Matasovic AWS, president of Oxo Equipment Co. and the Universal Welding Supply Co., highlighted the program.

Mr. Jefferson spoke on the selling job every individual will have to do to insure the future growth of welding. Mr. Matasovic showed colored slides taken during a trip to Russia in 1956 as a member of the State Department-sponsored tour in which representatives of agriculture and industry participated.

INERT-GAS WELDING

Kansas City, Mo.—The January 10th dinner meeting of the *Kansas City* Section was very well attended; and much interest was evoked by the speaker, Ed Dato AWS, of Linde Air Products Co., New York, whose subject was "Inert-Gas Welding—Past, Present and Future."

Mr. Dato's subject was illustrated by slides to show the present uses of inert-gas welding. Also, he explained how the present-day equipment is being modified, thus creating new equipment as well as new processes. The new thermal cutting process for aluminum was illustrated clearly with slides and Mr. Dato explained how early experiments led to the present development of the process. Illustrations of equipment in the experimental stage for welding the new types of metals were briefly discussed.

After the talk, a question and answer session was conducted and several points of interest clarified.

PLANT TOUR

Reading, Pa.—Ninety-six members and guests of the *Lehigh Valley* Section traveled by two buses to Reading, Pa., on January 7th, where they toured the plants of the Parish Pressed Steel Co.

Some of the facilities noted with interest were the manufacture of automobile frames. All operations, from the receiving of the raw material to the final paint drying stage, were shown to the group.

After the tour the members were guests of the company in the plant cafeteria for refreshments.

L. R. Constantine AWS, was in charge of the arrangements.

RESISTANCE WELDING CONTROLS

Manhasset, L. I.—The January 10th dinner meeting of the *Long Island* Section was held at Patricia Murphy's Candlelight Restaurant.

Guest speaker was William J. Farrell AWS, chief application engineer, Sciaky Bros. Inc. Prior to his association with Sciaky, Mr. Farrell was employed in the Research and Development Division of Consolidated Edison Co. of New York and also served with the Welding Engineering Department of Grumman Aircraft Eng. Corp., on Long Island. His subject for the session was "Dekatron Controls for Resistance Welding." The talk was very interesting and informative and considerable interest was shown by the audience.

APPLICATION OF WELDING

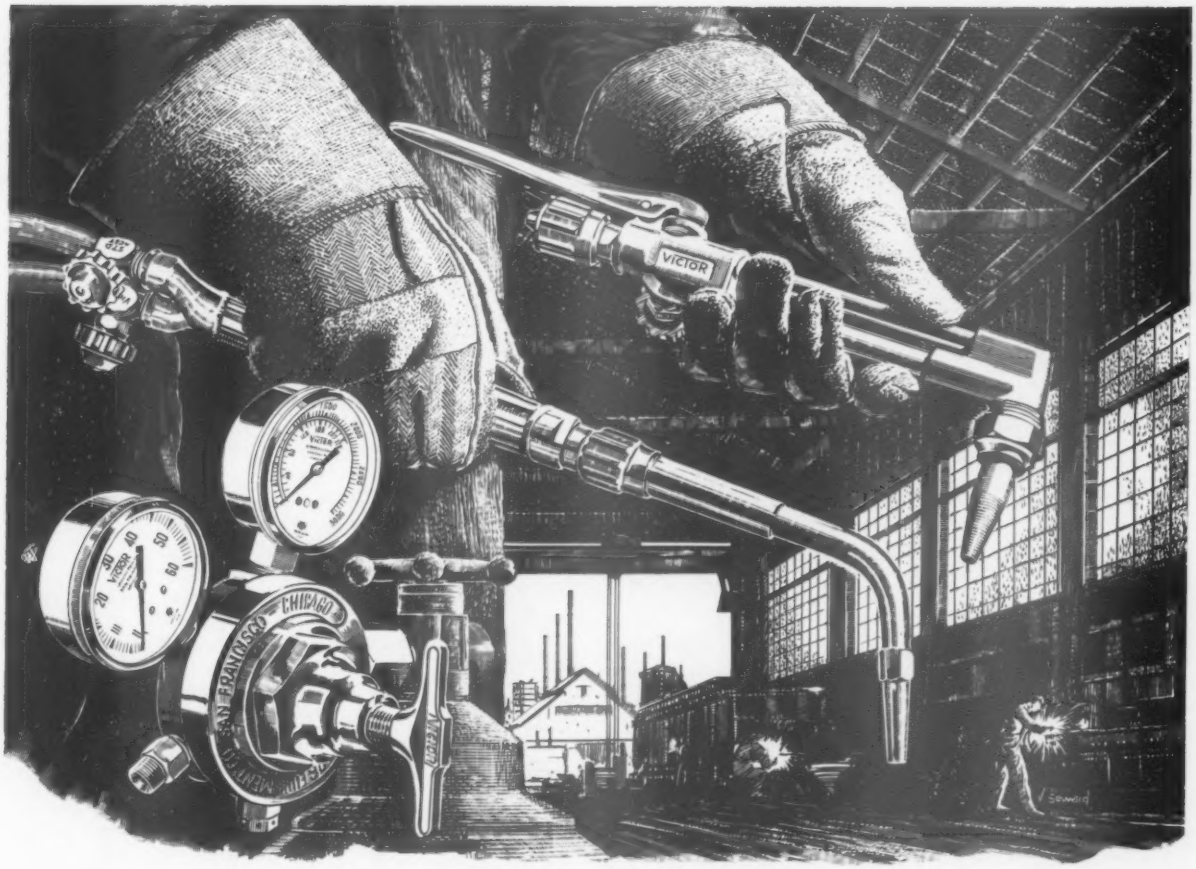
Huntington Park, Calif.—There was a meeting of the *Los Angeles* Section

SCIAKY HOST TO AIRCRAFT AND ROCKETRY PANEL

Members of Sciaky's Western Research Division who presented papers at January 10 meeting of Los Angeles Section Aircraft & Rocketry Panel. Left to right, are Sal Robellotto, Allen Crosby, Andre Windling, Ray Koepenick and Gene Lica

At officers and guests table, from left to right, are C. B. Smith, chairman of AWS Los Angeles Section; Mike Crawford, welding engineer, Boeing Airplane Co.; C. A. Carlson, assistant manager, Sciaky Western Research Division; Mario Ochieano, chairman of Aircraft and Rocketry Panel; Henry Guerin, manager of Sciaky Western Research Div.; Leo West, Panel vice-chairman; and Howard Eubanks, Panel secretary

Staff engineer at Sciaky Bros., Western Research Division, explains current analyzer to members and guests during January 10th meeting of Aircraft and Rocketry Panel of Los Angeles Section



the most flexible tools in the metal working industry

VICTOR COMBINATION WELDING & CUTTING UNITS

FOR EASE OF HANDLING DIFFERENT JOBS . . . Welding, brazing, hardfacing, heating, heat treating, descaling and paint burning. Cutting, trimming, deseaming and weld scarfing.

WITH A WIDE VARIETY OF NOZZLES, TIPS AND CUTTING ATTACHMENTS, with quick-change, hand-tight, time tested sealing ring connections.

RELIABLE FIELD-PROVED REGULATOR DESIGN for safe, dependable pressure and flow control.

See us at Booth 522
A.W.S. Philadelphia

See for yourself how easy it is to handle your work when you use Victor equipment. Ask your Victor dealer for literature or a demonstration.

VICTOR for welding

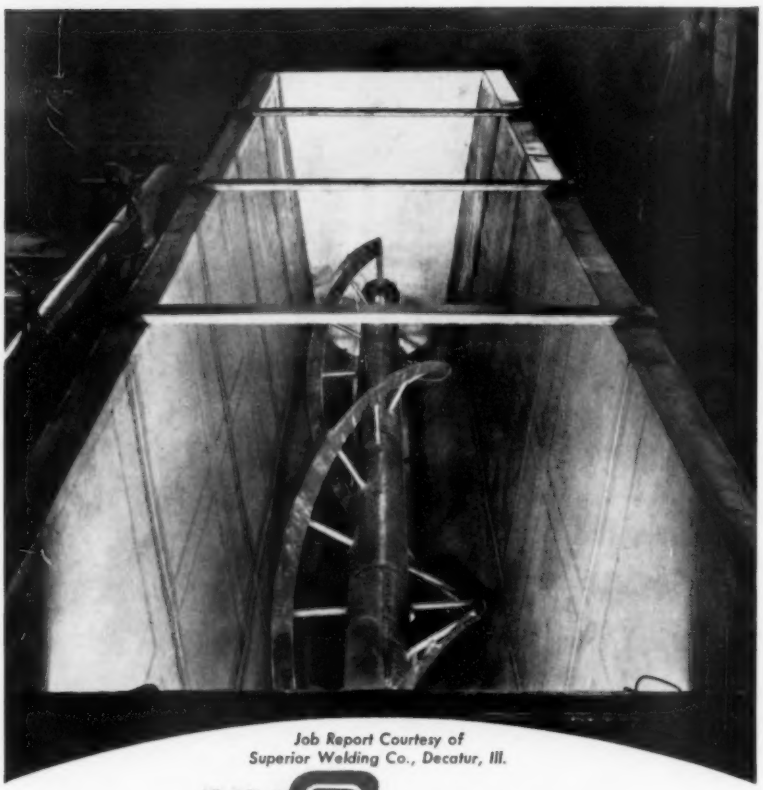
VICTOR EQUIPMENT COMPANY

Mfrs. of welding & cutting equipment; hardfacing rods, blasting nozzles; cobalt & tungsten castings; straightline and shape cutting machines.

844 Folsom St., San Francisco 7 • 3821 Santa Fe Avenue, Los Angeles 58

36

How to get longer service from stainless welded equipment



Job Report Courtesy of
Superior Welding Co., Decatur, Ill.

WELD WITH ARCOS

STAINLESS ELECTRODES

Processing certain foods in equipment such as this corn germ separator often releases acid by-products. These by-products, although weak, often corrode the equipment and contaminate the food unless the equipment is made of the "right" stainless. For welding the trough and agitator sections, two types of ARCOS Electrodes were used—Chromend KMo and Chromend 25/20 Mo respectively. These electrodes meet all the essentials: trouble-free welding, unbroken weld performance in service, and freedom from contamination. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.

on January 17th at the Elks Lodge, where 88 members and guests gathered for cocktails and dinner, and to enjoy a paper presented by Orville T. Barnett AWS, assistant manager of the Metals Research Division, Armour Research Foundation of Chicago. The title of Mr. Barnett's paper was "Which Weld and Why."

Mr. Barnett's talk was accompanied by charts covering the various phases of welding and weldable materials showing the proper process to be used in the welding, braze welding and brazing of different types of steels, cast iron, stainless steels and copper bearing alloys. The subject was well covered. Upon conclusion of his paper Mr. Barnett was presented with a pen set in appreciation of his contribution.

RESISTANCE WELDING

Los Angeles, Calif.—On the 10th of January, 135 members and guests of the *Aircraft and Rocketry Panel, Los Angeles* Section, gathered at the Sciaky Brothers Western Research Division to take part in one of the most outstanding meetings of the year. The agenda of the evening consisted of a well-planned program, starting with cocktails from 6:30 to 7:30, at which time all in attendance had an opportunity of reviewing the latest type of electronically-controlled resistance welding equipment available to industry. At 7:30 P.M. a delicious dinner was served. A short business meeting followed.

Speaker of the evening was H. Guerin, general manager of Sciaky's Western Research Division, and a man who has largely contributed to the Division's growth. Mr. Guerin's interest in resistance welding goes back to 1939, at which time he was instrumental in the installation and demonstration of the first Sciaky welder to arrive in this country. He is internationally known for a process developed by him to facilitate the fabrication of metal parts on the hydro-press with the use of rubber known as the Guerin process.

Master of ceremonies was assistant manager C. A. Carlson AWS, who had arranged the evening's program, including the presentation of five technical papers by staff members.

The first paper was presented by Gene Lica, electrical engineer. The title of his paper was "Aircraft Welding Equipment, Precise Electronic Control."

The second paper entitled "Aircraft Structures Welding," was presented by Ray Koepenick, AWS, laboratory supervisor.

The third paper entitled "Radiog-

raphy of Aircraft Structures," was presented by Dr. Andre Wendling, chief physicist and head of the Radiological Laboratory.

The fourth paper, presented by Allen Crosby, project engineer and head of the research division's Metallurgy Department, was entitled "Torsion Method of Quality Control."

The fifth and final paper was presented by Sal Robellotto AWS, project engineer. His paper was entitled "Projection Welding."

All papers were presented in condensed form with sufficient information to hold the interest of all those present.

IRON-POWDER ELECTRODES

Baltimore, Md.—Donald B. Howard AWS, supervisor, metallurgy and welding, for ACF Industries, Inc. was the speaker at the January 18th meeting of the *Maryland* Section held at the Engineer's Club in Baltimore.

Mr. Howard reported on the pioneer work done by his company in the use of iron-powder electrodes. He also described the evaluating characteristics of type E6012, E6020, E6024 and E6027 electrodes, particularly with reference to tensile strength and elongation properties. Mr. Howard's talk was very interesting and his presentation was enjoyed by all in attendance.

LADIES NIGHT

South Bend, Ind.—Thirty-eight persons braved wintry blasts in near-zero weather to attend *Michiana* Section's 7th annual Ladies' Night program held on January 17th at Russ' Restaurant. With a punch bowl for an "ice melter," a most enjoyable evening was under way. The program consisted of showing of two films: "Come to the North Land" shown through the courtesy of Northwestern Railway and "Acres of Power" furnished by the Oliver Corp. While the former showed relaxing scenes in America's northern lake and woodlands, the latter dealt with the development and manufacture of farm equipment and some scenes of welding in operation.

WELDED STRUCTURES

Milwaukee, Wis.—At the January 25th dinner meeting of the *Milwaukee* Section held at the Essex Hotel, Van Rensselaer P. Saxe AWS, consulting engineer from Baltimore, Md., gave a very interesting and educational talk on "Welding Structures." Mr. Saxe is well qualified to speak on this subject from his long

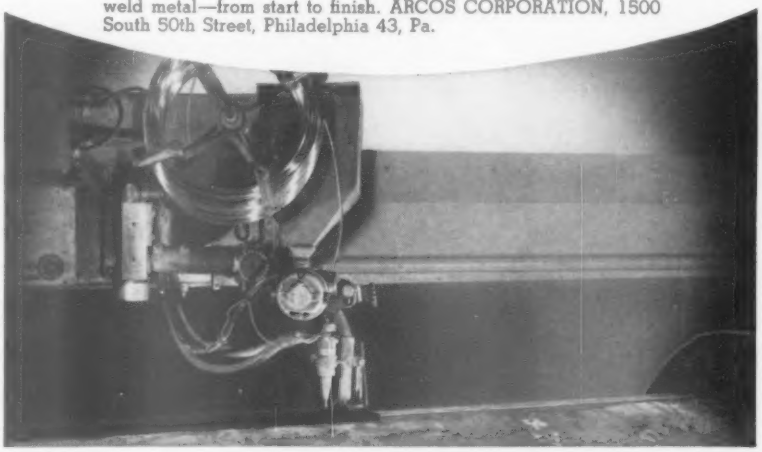
More proof . . . how to get *consistent* results from submerged arc welding

Courtesy of CF Braun & Co
Engineers and Constructors, Alhambra, California

WELD WITH ARCOS

STAINLESS COILED WIRE

Unfailing strength and resistance to corrosion at elevated temperatures are vital in the welds of this massive 14 ft. diameter, 30 ft. long catalyst pressure vessel. All seam welding of the 1¼ Chrome ½% Moly plate was submerged arc welded with Arcos Chromar *welding quality* wire. Arcos Chromar wire—like every Arcos filler metal product—can be used with confidence on the most critical jobs. Start with Arcos and be sure of uniform dependable weld metal—from start to finish. ARCOS CORPORATION, 1500 South 50th Street, Philadelphia 43, Pa.



years of experience in fabrication and consulting, as well as serving actively on many building codes.

Mr. Saxe pointed out the desirability and necessity of welded steel buildings from the standpoint of saving of steel, economic savings and flexibility of design, which is afforded through welded construction. He emphasized that welded construction of buildings is slowly increasing, but in order to step up the tempo of conversion from riveted or bolted construction to weldments, an educational program must be concentrated on structural designers or engineers, so that they will be assured that welding is safe, economical and flexible. Mr. Saxe's talk was illustrated by colored slides, and was very well received.

RESISTANCE WELDING

New York Mills, N. Y.—The *Mohawk Valley* Section met on January 10th in the auditorium of the New York Mills High School. A total of 16 attended. The low attendance was due to the subzero weather and very heavy snowfall. However, this was a good turnout considering that many other activities were cancelled due to the bad weather. A number of visitors from the Sperry-Rand Plant of Ilion, N. Y., were present.

Technical speaker was R. T. Gillett AWS consultant for Precision Welder and Machine Co. of Cincinnati. Mr. Gillett gave a very thorough talk on resistance welding. The talk was accompanied by slides and covered practically all phases of resistance welding from its accidental discovery in 1877 to today's modern methods and equipment. The speaker also displayed many samples showing resistance welding of various alloys.

CARBON-DIOXIDE WELDING

Omaha, Neb.—The *Nebraska* Section held its monthly meeting on January 13th at the Birchwood Club. The meeting was preceded by a social hour and dinner.

Guest speaker was John J. Chyle, director, Welding Research for A. O. Smith, Milwaukee, and AWS president. His topic was "CO_2 Welding and Its Application." Mr. Chyle pointed out such factors as power sources, rates of deposit, fit-ups, quality of welds, penetration and welding positions in the application of CO_2 welding methods.

The members and guests found Mr. Chyle's presentation to be very interesting and informative. The group also discussed steps which could be taken to create interest in the field of welding at high school and college levels.

RESISTANCE WELDING

Newark, N. J.—Forty-five members and guests attended the *New Jersey* Section's regular monthly dinner meeting held on January 15th at the Essex House Hotel in Newark.

A color film "Men, Steel and Earth Quake," was shown depicting the part played by steel in building construction to prevent damage by earthquake shock.

Due to a death in the family, the scheduled speaker, William J. Farrell AWS, of Sciaky Bros., Chicago, was unable to attend. However, Henry A. James AWS, of the same company very ably presented his paper on "Principles and Applications of Resistance Welding."

Mr. James spoke of the four basic features of resistance welding, spot, projection and flash welding and, with the help of slides, demonstrated the unusual and unique application for each of these methods. Mr. James gave the underlying reasons for the apparent lack of faith in spot welding, and how, through better control of pressure, heat and time, quality and quantity have been obtained.

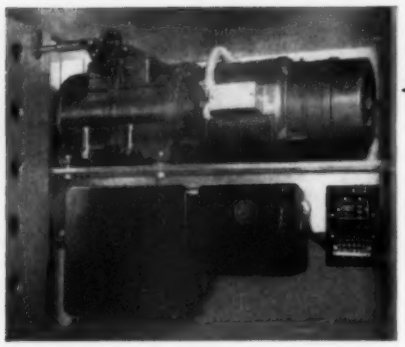
SPECIAL BRAZING ALLOYS

New Orleans, La.—The *New Orleans* Section met on January 22nd for its regular dinner meeting in the Engineer's Club of the DeSoto Hotel with some 40 members in attendance.

Guest speaker of the evening was

MAGNETIC BRAKE on TABLE ROTATION

Is STANDARD EQUIPMENT at no extra charge when you Buy ARONSON Precision Gear Driven POSITIONERS.



MAGNETIC BRAKE Built-In, gives smooth, exact stops for Table Rotation. No jockeying, forward and reverse, to get your weldment in Exactly the position you want. No danger to work and worker from overcoasting.

TEST FOR ACCURACY OF STOPS, 6000 LB. POSITIONERS Degrees Table Rotation After Pushing STOP Button:			
At 1 RPM Table Speed	Full Load	1/2 Load	No Load
WITH Magnetic Braking	2.6°	2.8°	3.0°
Without Magnetic Braking	12.7°	13.4°	15.2°

If any positioner without Magnetic Braking stops quicker than this test shows, that is a sign of too few Anti-Friction Bearings and not enough precision in its gearing. This condition causes too much drag and too much wear—a short life.

ARONSON MACHINES are 100% equipped with Ball Bearings or Timken Taper Roller Bearings — No Plain Bushings to wear out or require frequent servicing and periodic replacement.

All Gears Used in ARONSON Positioners are Precision Gears with High Strength — Low Friction.

Quality POSITIONERS by Aronson MACHINE COMPANY
ARCADE, NEW YORK

See the Ultimate in Geared Elevation Positioners in Booth 434 at the Welding Show, April 9–11, 1957

M. C. Robbins of Handy & Harman with "New and Special Brazing Alloys" as his subject.

Mr. Robbins gave a very interesting talk on the application and processes of silver solder and brazing. After his talk, a film in color was shown relative to his subject demonstrating the various methods of application and jigs that can be used.

Following the lecture and films by Mr. Robbins, another film was shown demonstrating the joining of nickel metals.

PRODUCTION BRAZING

New York, N. Y.—The first meeting of the new year of the *New York* Section was held on Jan. 8, 1957. An interesting program had been arranged and the speaker of the evening, James C. Powers AWS, director of training, Handy & Harman, N. Y., gave the audience a very interesting and educational lecture.

"Production Brazing," which was the topic, is a timely subject and, therefore, well chosen. Mr. Powers discussed the practical aspects of silver brazing as well as other forms of this process. He went into great detail on the types of automatic brazing equipment and explained the proper placement of alloys such as rings, washers, etc. Methods of aligning and holding parts in place during the process, both from a design state and production state were explained. The tolerances required, and the importance of keeping the surfaces from contamination and provided with sufficient flux, were outlined.

The talk was very well received, as evidenced by the number of questions that were asked the speaker after the talk. The committee responsible for the arrangements, as well as the audience, were pleased to have such an educational evening.

The meeting was held at the Victor Restaurant, 1 E. 35th St., New York City, where an excellent dinner was served prior to the meeting.

WELDING IN EUROPE

Olean, N. Y.—The *Olean and Bradford* Section held its January dinner meeting at the Castle Restaurant in Olean, on January 22nd with an attendance of 47 members and guests.

Guest speaker was Clarence E. Jackson AWS, of the Linde Air Products Co., Newark, and director of District Number 3. Mr. Jackson showed 75 slides taken while visiting plants in 11 European countries. Naturally, this was all very interesting.

STRUCTURAL WELDING IN EUROPE

Philadelphia, Pa. — Seventy-five members and guests of the *Philadelphia* Section attended dinner on December 17th held at the Engineer's Club and 100 were present for the meeting which followed.

Featured speaker was Clarence E. Jackson AWS, of the Linde Air Products Co., Newark and director of District Number 3.

Mr. Jackson described welding operations which he had observed in Europe during a recent 26-day, 4000-mile trip through 40 fabricating shops in 11 different countries. This trip was made with welding experts from several countries, under the auspices of the OEEC. Many excellent colored slides highlighted this extremely interesting talk, which was delivered before the annual joint meeting of the AWS and Society of Naval Architects and Marine Engineers. New developments in welding as well as

QUIZ PROGRAM HELD BY NORTH CENTRAL OHIO SECTION

Part of the 180 members and guests who attended the "Section Quiz" program sponsored by North Central Ohio Section on Dec. 7, 1956. Seated at the center table are, left to right, Gene Donathan, Oscar Rowlinson, Walt Edwards, judges, and Bob Ellison, program chairman

Left to right, Bob Kriz, Wasil Romance, John Diebold and Frank Flocke of Cleveland Section, the winners of the "Quiz"

North Central Ohio Section Chairman H. B. Cary is shown at extreme left. Others, left to right, are Dick Kewley, John Cooksey, Jim DeStefano and Tip Heestand of Stark Central Section; Bill Klingman, Gerry Schauerte, Bob Lossee and Tim Whalan of Cincinnati Section

Left to right, Jim Sapp, Merel Baughman, Tom Ellis and Ed Brenner of Toledo Section

PAGE offers a line of —the right packaging—the

In ever-increasing numbers, users of welding wire are looking to PAGE for their wire needs. The one biggest reason is that they have found that PAGE—in a unique degree—has the *facilities, experience* and *special skills* to draw and furnish exactly the right wire for your welding jobs. And behind that lies a story.

All Processes Closely Controlled

PAGE is *the one supplier* of welding wire who is in a perfect position to control the chemical and physical properties of its products all the way from billet to rod to finished wire. That is because we purchase our raw materials to rigid specifications; we select heats of carbon, low alloy and stainless steels for certain optimum characteristics—then, upon delivery to the mill, we analyze representative samples for compliance with PAGE specifications.

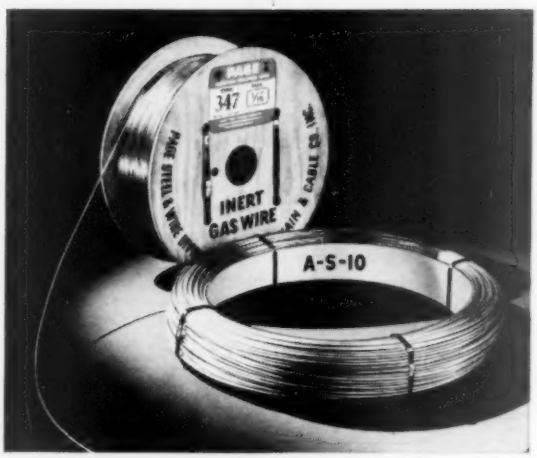
These purchasing and testing practices permit the production of wire capable of depositing weld metal which complies absolutely with welding requirements. *You don't have to compromise* when you buy, specify or use welding wire by PAGE!

Page Meets Today's Needs

One example of PAGE'S facilities for furnishing a wide range of quality-controlled welding wires for modern applications is shown by our stainless steel automatic welding wire. To meet needs of recent developments in the field of inert gas welding, PAGE offers fine wires (.020" to .09375") for use in semi-automatic arc welding machines in which the arc is shielded with argon, helium or CO_2 inert gas. These wires, wound on non-returnable plywood reels, furnish the utmost in convenience and freedom of wire feed.

Wire for All Types of Welding

You will find many advantages in standardizing on PAGE welding wire for your needs—whether for automatic or manual use . . . arc or gas welding of all types. Not only does PAGE offer a wide range of analyses, as shown in the column at the right, but we have unsurpassed facilities for manufacturing wire to any desired size, temper or surface finish—and can furnish it promptly, in many methods of packaging, through the convenient nation-wide PAGE Distributor service.



The Right Wire— Wide Analysis Range

There are *26 different analyses* in the PAGE line. These cover the field of applications: heavy automatic submerged arc...light manual submerged . . . inert gas manual . . . automatic, tungsten or metal arc.

AUTOMATIC WELDING WIRE

CARBON STEEL...Any carbon from Armco (.025 max.) to high carbon (.90-1.10)

LOW ALLOYS...All the most popular welding grades.

STAINLESS...All standard AISI grades. Other types on request.

GAS WELDING RODS

Since 1914, the standard of quality, uniformity and satisfactory performance. PAGE offers an exceptionally wide range of rods—furnished in 36-inch lengths, in coils or on reels in the following materials: Mild Steel • Armco • Low Alloy • Carbon Steel • Stainless Steel • Manganese Bronze • Naval Bronze

BARE ELECTRODES

PAGE Bare Electrodes are supplied in any carbon from Armco to high (.90-1.10) carbon.

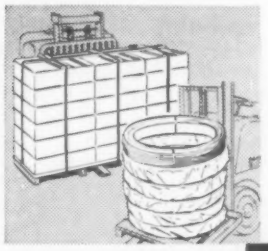
METAL SPRAY WIRE

Furnished as follows: Any carbon from Armco to 1.00 carbon • Low Alloy • Stainless Steel • Manganese Bronze • Naval Bronze

the right welding wires
right service—for modern needs

PAGE WIRES ARE PACKAGED RIGHT

PAGE Welding Wires are packaged in a wide variety of ways for the most complete protection and the utmost convenience in handling, in stocking and in use.

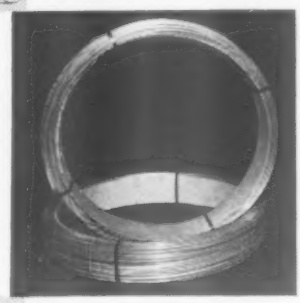


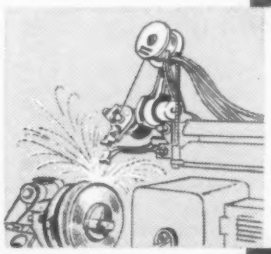
Wrapped Coils and Coils in Cartons

Single and palletized coils, each coil steel-strapped and wrapped in waterproofed paper. ...Also, coils in individual cartons, singly or palletized.

Welding Wire in Coils

PAGE A-S Automatic Welding Wire is regularly furnished in layer wound coils with cardboard liner, four Signode straps to facilitate coiling and easy unwinding.



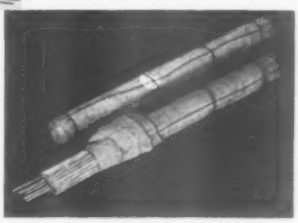


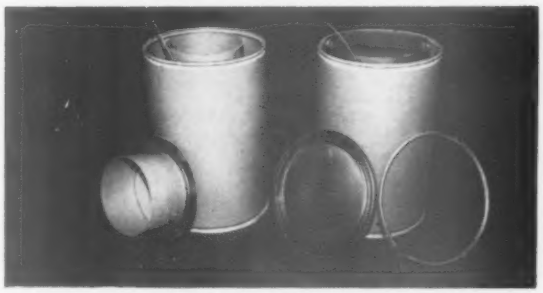
Handy Reels

PAGE Inert Gas Welding Wire is available on reels: Precision thread-wound on twenty-five-pound, non-returnable reels to fit all popular inert gas welding machines.

Gas Rod Packing

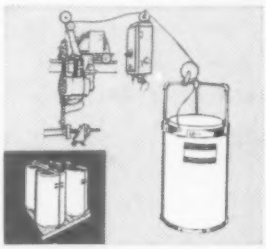
Gas welding rods are packed in 36" lengths in 50-lb. bundles—paper and burlap wrapped. Also in coils and reels (approx. 150 lbs.)—burlap wrapped. Stainless rods also come in 10-lb. fibreboard cartons.





LEFT: Pay-off-pak ready for filling, with "wire slinger" for uncoiling at extreme left. RIGHT: "Wire slinger" installed for feeding out wire; also, below, re-usable lid and retaining ring. Ring insures smooth feed-out of wire without snarls or kinks.

Sketch at right shows Pay-off-pak for continuous feeding up to 500 lbs. of wire without rethreading. Also (inset) lightweight Leverpaks. Both these containers protect against coil distortion... are easily opened, resealed, handled, stored.



PAGE Service Means Prompt Delivery From Local Stocks

You can get PAGE automatic arc welding wire, or oxy-acetylene welding rods quickly and easily from your nearby PAGE Distributor.

PAGE Distributors carry ample stocks from which your requirements can be filled without delay or inconvenience to you. This handy service not only saves you time in getting what you need, but makes it unnecessary for you to make a sizeable investment in inventory.

Send For These

Folder **DH-402A**—PAGE Submerged Arc and Inert Gas Welding Wire.

Booklet **DH-1277**—PAGE Gas Welding Rods.

Write our Monessen, Pa., office for *either or both*

Meet us at BOOTH 634
WELDING SHOW
Convention Hall
PHILADELPHIA
April 9-11, 1957

ACCO products

ACCO
TRADE MARK

Page Steel and Wire Division
AMERICAN CHAIN & CABLE

Monessen, Pa., Atlanta, Chicago, Denver, Detroit, Houston, Los Angeles, New York, Philadelphia, Portland, Ore., San Francisco, Bridgeport, Conn.

Better Value

AT JANUARY MEETING OF PUGET SOUND SECTION

Members and guests in attendance at the smorgasbord dinner of the Puget Sound Section on January 10th, prior to trip to Atlas Foundry Co.

Speaker Stan Marshall is shown addressing the meeting. E. Kinnaird is at left and W. H. Downing is at right

many time-honored methods appeared on the screen as the scene shifted from shipyards in Sweden to Italy and other localities. There were also many fine scenic views which helped emphasize the differences in various countries. Mr. Jackson's observations as a welding expert were well received by this well-attended meeting, which was equally impressed by the pictures taken during his rapid tour of Europe.

PAST-CHAIRMEN NIGHT

Philadelphia, Pa. — The regular meeting of the *Philadelphia* Section held on January 21st at the Engineers Club honored the past-chairmen of the Section, and was attended by the following past-chairmen: R. D. Thomas, 1927–28; J. J. Dunne, 1929–30; L. H. Christensen, 1931–32; C. I. MacGuffie, 1936; H. W. Pierce, 1942–43; A. A. Holzbaur, 1945; E. R. McClung, 1947; H. J. Irrgang, 1948; L. D. T. Berg, 1949; K. W. Ostrom, 1951; R. A. Guenzel, 1952; R. D. Bradway, 1953; R. D. Thomas, Jr., 1954; E. E. Goehringer, 1955. Mr. Thomas, Sr., sketched the early Section days with many interesting anecdotes of that era.

Lew Gilbert AWS, executive editor of *Industry and Welding*, drew from his vast experience in various phases of welding to present an authoritative talk on improving quality and efficiency of welding production through proper shop management.

PLANT TOUR

Tacoma, Wash.—Fifty-one members and guests attended the January meeting of the *Puget Sound* Section held on January 10th at Steve's Restaurant, where a smorgasbord dinner was thoroughly enjoyed.

Speaker of the evening was Stan Marshall, production engineer of Atlas Foundry, who described the growth of his company from 1899 to its present operation that now covers 11 acres. He discussed the problems encountered in the repair and salvage of iron and steel castings. At the conclusion of his talk the Section made a complete tour of the Atlas Foundry under the expert guidance of Stan Marshall, Bill Gibbs and Joe Baresa.

TOOL STEEL WELDING

Rochester, N. Y.—On Monday, January 21st, R. K. Lee, AWS, vice-president of the Alloy Rods Co., spoke at the dinner meeting of the *Rochester* Section held at the Liederkranz Club. Forty members and guests were present to hear Mr. Lee talk on "Arc Welding of Tool Steels."

Application of Mr. Lee's talk to shop practices can result in considerable savings from the repair of chipped or worn tools and dies, or from the composite fabrication of inexpensive base material overlaid with a hardenable tool-steel weldment. Mr. Lee, in his talk, broke down the classification of tool steels into six general categories: air hardening, water hardening, oil hardening, work hardening, high speed and hot work.

Mr. Lee covered the 5 steps in procedure as follows:

(1) Materials should be typed into one of the above six categories according to the required heat treatment and quenching. This classification automatically determines the electrode used.

(2) The surface of the material should be prepared to sound metal, i.e., to remove all surface scale, checks, and unsound metals.

(3) $^1/_8$ to $^1/_4$ in. of weld metal should be deposited over the base material in order to insure sound weldment and sufficient support.

(4) Preheat to and maintain interpass temperatures equivalent to the drawing or tempering temperature recommended for the category of steel. On hardened pieces, a full anneal prior to welding is the safest practice to insure against base-metal cracking.

(5) In many cases tool steel overlay may be used as welded after suitable drawing or tempering. If entire base requires hardening it should be heat treated according to the specifications for the particular steel.

He also called attention to some precautions that should be kept in mind. Recommendations for various categories were also given in detail.

Slides were used to illustrate Mr. Lee's fine and detailed talk and a rising vote of thanks was given to him.

OXYGEN CUTTING

Shreveport, La.—A talk on oxygen cutting entitled "Fire and Earth" was given by R. L. Deily AWS of Air Reduction Sales Co., New York, at the January 17th dinner meeting of the *Shreveport* Section held at Captain Shreve Hotel.

Mr. Deily's talk covered oxygen cutting from the standpoint of everyday operation as well as background information on oxygen and iron in the steel industry. A movie entitled "Burning Blades" was shown in conjunction with the talk.

In the USA thirty billion cubic feet or 1.2 million tons of oxygen were produced last year and 2500 million tons of oxygen were used in the process of burning fuel ($2^1/_2$ lb oxygen to burn 1 lb fuel). With this large amount of oxygen being taken out, there has been no noticeable change in 22.99% oxygen in atmosphere. Much of this oxygen has been used in steel production which was 120 million tons last

year. By the year 1960, it is estimated that 2.4 million tons of oxygen and 140 million tons of steel will be produced.

Mr. Deily discussed and described six essential factors in any mechanized cutting and welding process as follows: (1) a materials handling system; (2) a machine designed for the job; (3) an operator station with controls; (4) a gas or power system engineered for adequate supply; (5) a known process; and (6) trained personnel.

THERMAL CUTTING

Witchita, Kan.—Ed Dato AWS, of the Linde Air Products Co., N. Y., was the speaker of the January 7th dinner meeting of the *Wichita* Section held at Sidman's South Seas Restaurant. An attendance of 60 were on hand for the dinner and 90 were present for the meeting which followed.

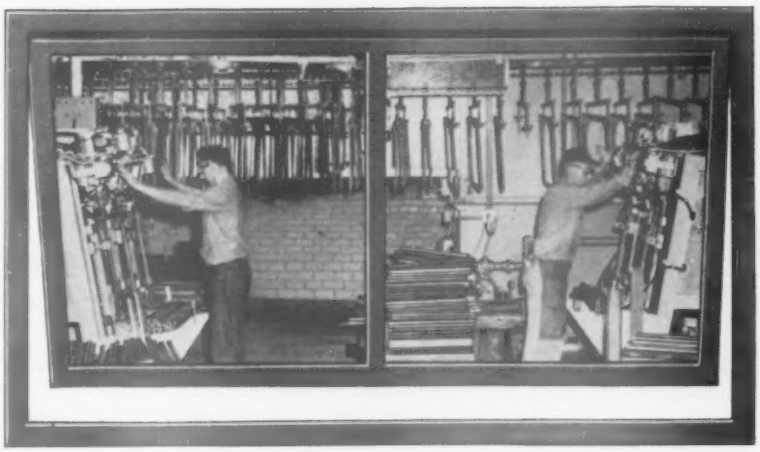
Mr. Dato spoke on the new inert-gas arc cutting of nonferrous metals developed by his company. Slides were used to illustrate and supplement the talk. A lengthy discussion period followed where many production problems were talked over. Mr. Dato is a former member of the Wichita Section.

NONFERROUS METALS

Worcester, Mass.—A snow storm kept the attendance down to 42 people at the dinner meeting of the *Worcester* Section held on January 7th at Nick's Grille. Under ordinary weather conditions a much larger turnout would be present to hear the speaker of the evening, John W. Mortimer, AWS, of Pratt and Whitney Aircraft, Hartford, Conn. Mr. Mortimer is well known to the members of this Section, since he has successfully addressed them several times in the past. His experience with nonferrous materials is extremely wide.

Mr. Mortimer explained in detail the processes and procedures used in joining copper, silver, Monel, Inconel and numerous stainless and aluminum alloys, and many others.

Mark Your Calendar
Now for
FIFTH AWS WELDING SHOW
April 9–11, 1957
and
ADAMS NATIONAL MEETING
April 8–12, 1957
Philadelphia, Pa.



RESISTANCE HOT-HEADING CASEMENT WINDOW UNITS

Production . . . . . Up 40%
Unit Labor Cost . . . . Down 50%
Inspection . . . . . Eliminated
Morale . . . . . Improved

Production of steel window frames and sash was increased by 40% and labor costs cut in half when the U. S. Gypsum Co., Warren, O., installed two Taylor-Winfield resistance welders to join parts of the two assemblies. Because of the consistent quality of the hot upset joints, the firm reassigned an inspector who formerly checked the sash and frame sections. Officials also report improved worker morale and less fatigue due to eliminating noisy air hammers that previously cold-headed the sash and frame joints.

In this streamlined assembly operation, one machine joins frames and the other joins sash. The operators place the frame and sash parts in position, where they are automatically clamped. Pairs of frame and sash go through further processing together. Adjustable tooling permits assembly of all sizes of frame and sash manufactured by U. S. Gypsum.

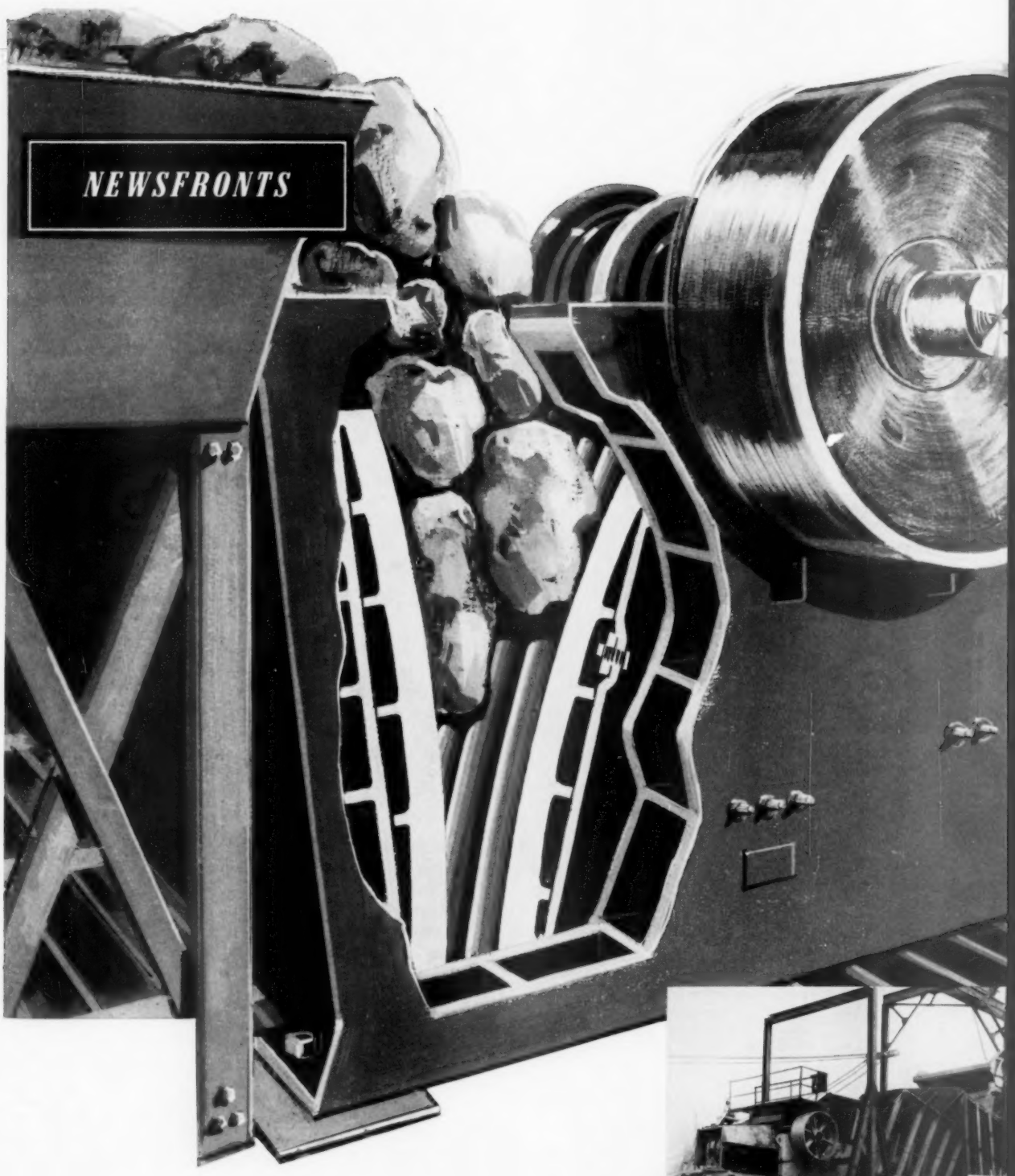
SEE OUR BOOTH 400
5TH AWS WELDING SHOW
April 9-11, '57
CONVENTION HALL
PHILADELPHIA, PA.

Finding means of increasing your production and lowering your fabrication costs is Taylor-Winfield's business. Contact the nearest T-W office.

The TAYLOR·WINFIELD *Corporation*
WARREN, OHIO

ELECTRIC RESISTANCE AND ARC WELDING MACHINES
Sales and Service
CHARLOTTE • CHATTANOOGA • CHICAGO • CLEVELAND • DALLAS
DAYTON • DENVER • DETROIT • LOS ANGELES • PHILADELPHIA
PORTLAND, OREGON • SEATTLE • ST. LOUIS • STAMFORD
OAKVILLE AND WINDSOR, ONTARIO

NEWSFRONTS



▲ The immense power and strength of Pioneer crushers are evidenced by the fact that the unit shown here takes rock up to 40″ x 46″ and reduces them to sizes as small as 7″. And it does so at the rate of 700 tons per hour!

Both internal and external welds must have tremendous impact resistance. In fact the entire unit must be as trouble-free as practicably possible because most crusher installations are made at considerable distance from any service and repair facilities. ▶

Giant 4248 crusher built to thrive on a diet of 4ft. boulders!

Imagine the terrific strains the welds take when this crusher smashes a four-foot boulder into baseball-sized rocks. That's why Pioneer Engineering Works builds it with A. O. Smith electrodes for the critical welds.

Here's another example of how leading manufacturers safeguard the performance and life of their products by welding with A. O. Smith electrodes.

Pioneer Engineering—Division of Poor & Company (Inc.,) Minneapolis, Minn., builds a line of process equipment that must stand up under rugged service. Thus, crusher bases, which take a constant beating, are welded with A. O. Smith electrodes. Rods include SW-35 (AWS E-6020) for deep penetration . . . and SW-15 (AWS E-6013)—America's most famous all-position high-production electrode.

If, like Pioneer, you use welding in your business, you'll find it pays to insist on A. O. Smith welding electrodes. You'll find their consistent high quality and uniformity help you get the job done faster, better and at lower overall cost. Why not get the complete story from your man from A. O. Smith.

The man from A. O. Smith

John Rehm is the A. O. Smith weld-consultant who works with Pioneer. More than a salesman, he's a welding specialist ready and eager to help with any welding problem you may have.

PRODUCED BY WELDERS . . . FOR WELDERS . . . Because welding is our full-time business, we offer you America's finest welder-proved electrodes, machines and accessories.

Through research A.O. Smith *. . . a better way*

A.O.Smith

CORPORATION

WELDING PRODUCTS DIVISION

Milwaukee 1, Wisconsin

International Division: Milwaukee 1, Wisconsin

New Members

Effective January, 1, 1957

MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member

D—Student E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	*132*
Members	*5,774*
Associate Members	*6,168*
Students	*189*
Honorary Members	*8*
Life Members	*15*
Total	*12,286*

A.W.S. Builds Men of Welding

ARIZONA

Moore, J. Paul (C)

BIRMINGHAM

Curphey, Thomas L. (B)
McCahan, Robert D. (C)

BOSTON

Donovan, Robert E. (B)
Dubuc, Arthur (C)
Russell, Richard W. (B)

BRIDGEPORT

Woodruff, Vernon C. (C)

CANADA

Dudman, K. (B)
Fauthier, Leon (B)
Stalany, W. (B)

CHICAGO

Baugh, Edwin D. (B)
Fenwick, Cecil (B)
Gorman, Charles V. (B)
Gould, Robert J. (C)
Limacher, John (B)
Musson, Elmer E. (B)
Neilsen, A. L. (B)
Ozimek, Theodore W. (B)
Peplow, Marvin W. (B)
Showerman, John T. (C)
Walton, Robert T. (B)
Watrous, Eugene T., Jr. (C)
Zick, Leonard P. (B)

CLEVELAND

Bose, Robert N. (C)
Hadde, Leonard H. (B)
Matlow, George (B)

COLUMBUS

Cline, Cecil (D)
Kaluza, Edward F. (D)
Lewis, Wallace J. (C)
Long, Frank M. (D)
Marble, Arthur E. (D)

DALLAS

Cagle, A. L. (C)
Catina, Tony (B)
Duncan, Harold L. (B)

DAYTON

Aughe, Donald G. (C)
Rife, Walter M. (C)
Wilson, Daniel A. (C)

DETROIT

Cox, Walter A. (B)
Denison, Cecil R. (B)
Dolan, Edward F. (B)
Lawrence, Robert (B)
Metzger, A. F. (C)
Smith, George W. (C)
Sperry, Harman F. (B)
Strachan, Peter (B)
Yarwood, George (B)

FOX VALLEY

Dwyer, John R. (C)

HARTFORD

Havens, Relf R. (C)
Leyden, Frank A. (B)
Lorence, Michael (B)

HOUSTON

Black, Jess R. (B)
Marsae, J. F. (C)
Richmond, W. D. (C)

IOWA-ILLINOIS

Farber, William E. (B)
Hampton, William T. (C)
Lower, Robert M. (C)
McDaniel, Thomas (B)

LEHIGH VALLEY

Foltz, William A. (C)
Roberson, James (B)
Sines, George W. (B)

LONG BEACH

Aguitar, Jim S. (D)
Crouse, Lester L. (D)
Fuedge, Rodney Edwin (D)
Martin, Billy Rush (C)

LOS ANGELES

Barnett, James E. (C)
Daniels, Jack (C)
McElhany, Paul G. (B)
McKiney, Clifford T. (C)
Petersen, Carl (B)

MADISON

Anderson, Arlan O. (C)
Benkovich, Boris (B)
Burchik, Joseph (B)
Chadwick, William H. (B)
Champnoise, Donald J. (C)
Christiansen, Earl (C)
Eickhoff, Henry (B)
Fessenden, Wayne L. (C)
Fosdal, Elmer C., Jr. (C)
Graves, Robert W., Jr. (B)
Heimbecker, Charles (B)
Jakubenas, R. (C)
Knowles, Lawrenz E. (C)
Lamia, Andrew J. (B)
Lauridsen, James M. (B)
McGuire, James G. (B)
McMillen, Carrel C. (C)
Meyers, D. J. (B)
Minter, Leroy M. (C)
Needham, Damian Oscar (C)
Okas, John T. (B)
Overland, Edwin F. (C)
Pollard, John A. (B)
Schuetz, Michael (B)
Storch, Alois W. (B)
Trapino, Peter (C)
Voeck, Donald G. (B)
Wirestad, Richard (B)

MARYLAND

Caprarola, Joseph, Jr. (C)

MILWAUKEE

Atwell, Herbert L. (B)
Drinka, Martin G. (C)
Gair, Robert W. (C)
Limberg, Reuben A. (C)
Ware, Warren (C)

NEBRASKA

Oberg, Ivar (B)
Van Orsdel, Joe (C)

NEW JERSEY

Adamec, Edward J. (B)
Bisbing, Paul (B)
Burggaller, Fred E. (C)
Caiezza, Michael (C)
Freytag, Donald R. (C)
Gerrard, John (C)
Hamann, R. E. (B)
Kelly, Christopher G. (B)
Lotti, Gilbert (C)
Picerno, Victor (C)

NEW ORLEANS

Barnard, J. B. (B)
Brooks, D. A. (B)
Ferree, E. B. (B)
Graves, James E. (B)
Lousteau, Paul R. (B)
Morris, Harold I. (B)

NEW YORK

Charlip, Steven (C)
Knackstedt, Henry (B)
Riff, Solomon B. (B)

NIAGARA FRONTIER

Albers, Glen L. (B)
DeWein, Karl (C)
Padden, Charles F. (D)

NORTH CENTRAL OHIO

Mackey, Glenn C. (C)

NORTHERN NEW YORK

Perreault, Paul E. (C)
Whaley, Neil L. (C)

NORTHWEST

Erickson, Leonard A. (C)
Schardin, Harold E. (B)

OKLAHOMA CITY

Barnes, Arvin J. (B)
Sallee, Manson (C)

OLEAN-BRADFORD

Hull, William John (B)

PASCAGOULA

Huggins, J. S. (B)
Thompson, L. W. (B)

PEORIA

Brown, Robert M. (C)
Chin, Kayon W. (C)

PHILADELPHIA

Collins, John R. (C)
Deakyne, David W. (C)
Edmonds, Philip L. (C)
Fullen, David J. (C)
Hilbert, Francis E. (B)
Hufnal, Edmund T. (C)

PITTSBURGH

Grisell, Charles P. (B)

RICHMOND

Duvall, L. W. (C)
Small, James E., Jr. (B)

ROCHESTER

Payne, Burton S., Jr. (C)
Vande Sande, James R. (C)

Rene D. Wasserman, President, Eutectic Welding Alloys Corporation,

Sends an Invitation to Industry

Low Temperature EUTECTIC WELDING ALLOYS

"The eye is not satisfied with seeing"

SUNDAY SCHOOL is one of America's traditional institutions; here our children of all religions have the seeds of faith brought to flower.

National Sunday School Week is being observed this year from April 8 through April 14. The Laymen's National Committee, an all faiths organization, has chosen for this year's theme: "SUNDAY SCHOOL – SOURCE OF SPIRITUAL STRENGTH."

Moral faith is the backbone of the free world's strength. Instilling this faith in our children is the first step toward a better tomorrow.

Laymen's National Committee, Inc., Hotel Manger Vanderbilt, N. Y. 16, N. Y.

NATIONAL SUNDAY SCHOOL WEEK

APRIL 8-14

SAGINAW VALLEY

Durkin, John J. (D)
Dutton, Fred O. (B)
McGill, Donald S. (C)

ST. LOUIS

Berry, Macy M. (C)
Broz, Frank J. (B)
Martinson, Warren C. (C)

SAN ANTONIO

Cope, H. Dale (C)
Garza, Gaspar T. (C)
Marin, Alfonso (C)

SAN FRANCISCO

Cardinal, Orville P. (C)
Cordova, Floyd S. (D)
Cramer, James O. (D)
McQueen, Harold J. (C)
Romero, Thomas L. (C)
Van Linden, Ralph A. (B)

SANGAMON VALLEY

Anderson, Norman R. (C)
Brake, J. Floyd (C)
Clinton, E. C. (B)
Hartness, Robert A. (C)
Heitman, Ray B. (C)
Higar, Leo H. (C)
Livingstone, William L. (C)
Mellinger, Stanley (C)
Seman, Joseph J. (C)
Trueblood, David L. (C)

SHREVEPORT

Neher, M. Ray (C)

SOUTH FLORIDA

Hinkle, Don L. (C)
McCullough, E. K. (B)

STARK CENTRAL

Angel, William A. (B)
Daughenbaugh, Floren S. (B)
Grimes, Kenneth (B)
Hattersley, Robert F. (C)
Krause, Morton D. (B)
Pariano, Albert B. (C)
Stenger, Heber L. (B)
Wilson, William H. (B)

SYRACUSE

Arrain, William E. (C)
Podsiadlo, Edwin L. (C)

TOLEDO

Moran, J. J. (B)

NOT IN SECTIONS

Auger, Arthur L. (C)
Beebe, Fred (C)
Blake, Albert L. (B)
Cutting, George L. (B)
Hill, Guild F. (C)
LaRose, Joseph A. (C)
Marchand, Julien A. (C)
Phillips, James (B)
Pinard, Lionel (B)
Proulx, George O. (C)
Pumphrey, William Idwal (B)
Robillard, Armand J. (B)
Schryver, Jacob B. (C)
Schryver, William (C)
Tinkham, Roland C. (B)
Turcotte, Leo (C)
Worrell, Cromer Y. (B)

Members Reclassified

During the Month of January

LONG BEACH

Pope, Frank C. (C to B)

LOS ANGELES

Collipriest, James E., Jr. (D to C)

MADISON

Kujak, Arthur J. (C to B)
Stanley, T. D. (C to B)

PORTLAND

Ammerman, Richard F. (C to B)

SALT LAKE CITY

May, Samuel Thomas (C to B)

SAN ANTONIO

Bergeron, John E. (C to B)

EMPLOYMENT SERVICE BULLETIN

Position Vacant

V-341. Specialist in soft soldering and brazing, with upwards of ten years' experience required for part-time consulting. New York City area.

Services Available

A-693. Executive Engineer. 41 years of age. Moving to Los Angeles. Heavy background in metal industry covering manufacturing methods, estimating, engineering, design, research and plant layout. Wide experience in fabrication and welding of carbon and alloy steels, stainless, Monel and aluminum, using manual and automatic equipment. Detailed knowledge of pressure vessels, heavy machinery, chemical equipment and railway and highway bridges. Registered professional metallurgical engineer of Ohio and licensed professional engineer of New York.

Tempilstik° FOR ALL HEAT-DEPENDENT OPERATIONS

looks like a crayon... marks like a crayon... tells temperatures like a precision instrument!

Available in these Temperatures (F.)

113	375	1000
125	388	1050
138	400	1100
150	413	1150
163	425	1200
175	438	1250
188	450	1300
200	463	1350
213	475	1400
225	488	1450
238	500	1500
250	550	1550
263	600	1600
275	650	1650
288	700	1700
300	750	1750
313	800	1800
325	850	1850
338	900	1900
350	950	1950
363		2000

Sixty-three different compositions enable you to determine and control working temperatures from 113° to 2000° F.

TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures — plus or minus 1%.

ALSO AVAILABLE IN LIQUID AND PELLET FORM . . . WRITE "WELDING SALES" DEPT. FOR SAMPLE TEMPIL° PELLETS . . . STATE TEMPERATURES OF INTEREST—PLEASE!

Tempil° CORPORATION 132 WEST 22ND STREET, NEW YORK 11, N. Y.

Visit us at Booth 629—April 9–11, Welding Show, Philadelphia, Pa.

FASTER . . . EASIER HARD SURFACING

Semi-Automatically With

Wear O Matic

PRECISION DRAWN HARD SURFACING WIRES

Now you can shorten "down-time" and turn out more resurfaced or rebuilt parts per shift with semi-automatic equipment and Wear-O-Matic precision drawn hard surfacing wires. With deposition rates up to 15 pounds per hour you can easily save up to 50% of the cost of manual hard surfacing operations and yet retain the flexibility of manual welding. In addition, with semi-automatic application there is no stub or coating loss.

See semi-automatic demonstrations of Wear-O-Matic wire. **Visit Booth 101 at the AWS Welding Exposition, Convention Hall, Philadelphia.**

Here's why Wear-O-Matic is the RIGHT WIRE for your semi-automatic applications.

More uniform wear resistance Wear-O-Matic wires are compacted to a density almost equal to solid wire resulting in a more uniform hardness and wear resistance throughout the weld deposit.

Continuous smooth feeding The true diameter and dense structure of Wear-O-Matic wire permits smooth feeding without special feed rolls or contact tubes. Wear-O-Matic wires will not crush under standard feed roll pressure.

Find out now how Wear-O-Matic precision drawn wires can improve your hard surfacing operation. Write for free literature and application manual. Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

Drawalloy

CORPORATION

YORK, PENNSYLVANIA

THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL

Current Welding Literature

For copies of articles, write directly to publications in which they appear

Aircraft Engine Manufacture. Ryan Gets 133% Increase in Roll-Spot Welding Speeds. *Industry & Welding*, vol. 29, no. 10, (October 1956), pp. 119–20, 122.

Aluminum and Aluminum Alloys. Removal of Oxide from Aluminum by Brazing Fluxes, M. F. Jordan and D. R. Milner. *Inst. Metals—Jnl.* vol. 85, pt. 2 (October 1956), pp. 33–40, 1 plate.

Automobile Manufacture. Automation and Conveyors Cut Stamping Costs at Ford, A. H. Allen. *Tool Engr.*, vol. 37, no. 1 (July 1956), pp. 98–101.

Bridges. End-Welded Studs as Shear Connectors in Composite Bridges. *Roads & Eng. Construction*, vol. 94, no. 9 (September 1956), pp. 67–68, 162.

Bridges. New Welded Continuous Girder Bridge, H. G. Jarman. *Welding & Metal Fabrication*, vol. 24, no. 9 (September 1956), pp. 306–307.

Bridges. Oxygen Cutting Gets Big Job. *Ry. Track & Structures*, vol. 52, no. 6 (June 1956), pp. 48–49.

Bridges. Viaduct Sets Welded-Girder Record. *Eng. News-Rec.*, vol. 157, no. 18 (November 1, 1956), pp. 43–44, 46.

Costs. Arc Welding Costs: Example of Total Production Analysis, A. G. Thompson. *Brit. Welding Jnl.*, vol. 3, no. 9 (September 1956), pp. 403–414.

Distortion Control. How to Control Weld Distortion Within Close Limits, J. Mikulak. *Iron Age*, vol. 178, no. 9 (August 30, 1956), pp. 88–90.

Earthmoving Machinery. Welded Design Used in Bucket for Dragliner, F. Loos. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 52, 55.

Education. Functions and Education of Welding Engineers. *Brit. Welding Jnl.*, vol. 3, no. 9 (September 1956), pp. 398–402.

Education. Welding Education: Time and Money, H. J. Nichols. *Can. Metals*, vol. 19, no. 7 (July 1956), pp. 28–29.

Electric Cables. New Flux for Soldered Joints in Aluminum Conductor Cable. *Light Metals*, vol. 19, no. 222 (September 1956), pp. 274–275.

Health Hazards. Controlling Health Hazards in Soldering Operations, W. Schweisheimer. *Tool Engr.*, vol. 37, no. 3 (September 1956), p. 90.

Hydraulic Turbines. Application of Welded Design to Hydraulic Turbine and Valve Manufacture, J. G. Warnock. *Eng. Jnl.*, vol. 39, no. 10 (October 1956), pp. 1350–1359.

Inert-Gas Welding. Carbon Dioxide Shielded Self-Adjusting Arc Welding of Mild Steel, A. R. Muir. *Welding & Metal Fabrication*, vol. 24, no. 9 (September 1956), pp. 328–333.

Inert-Gas Welding. Welding Steel by Inert-Gas-Shielded Metal-Arc Process, A. R. Muir. *Sheet Metal Industries*, vol. 33, no. 353 (September 1956), pp. 599–605, 613–614; (discussion) 614–616.

Iron Castings. New Twist Cuts Cost 50%, C. J. A. Dorizzi. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 43–44.

Maintenance. Maintenance Should Be Routine. *Welding Engr.*, vol. 41, no. 7 (July 1956), pp. 42–43.

Management. Shop Management for Better Welding, L. Gilbert. *Industry & Welding*, vol. 29, no. 10 (October 1956), pp. 124–126, 129–133.

Mufflers. Muffler Has All-Welded Design. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 46, 48.

Nuclear Reactors. Portable Reactor Has Welded Gold Lining. *Can. Metals*, vol. 19, no. 10 (October 1956), pp. 26, 28.

Pipe. Welded Pipe Lining for Aussie Dam, J. Grinrod. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 58–59.

Pipe Lines. Pipeline Radiography, H. Hovland. *Brit. Welding Jnl.*, vol. 3, no. 9 (September 1956), pp. 387–391.

Rails. Reducing Butt-Welding Costs. *Ry. Track & Structures*, vol. 52, no. 7 (July 1956), pp. 34–37.

Rolling Mills. Sheffield Strip Mill. *Civ. Eng.* (Lond.), vol. 51, no. 604 (October 1956), pp. 113–114.

Shipbuilding. Trends in Modern Shipyard Development: Review and Outlook, J. H. Krietemeijer. *Brit. Welding Jnl.*, vol. 3, no. 10 (October 1956), pp. 448–457.

Soldering. Reliable Soldered Connections Without Mechanical Joints, J. R. Smith. *Elec. Mfg.*, vol. 58, no. 3 (September 1956), pp. 143–145.

Soldering. Soldering in Controlled Atmosphere, A. C. Starrenburg. *Machine & Tool Blue Book*, vol. 51, no. 10 (October 1956), pp. 136–140.

Structures. Design for Structural Welding, L. Grover. *Roads & Streets*, vol. 99, no. 4 (April 1956), pp. 99–105, 108, 110.

Structures. Resistance Welding Used on Beams for Power Stations. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 39–40.

Surfacing. Hardfacing Does Job Despite Initial Customer Resistance, A. Bromberg. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 37–38.

Surfacing. New Division's New Plant. *Can. Machy.*, vol. 67, no. 10 (October 1956), pp. 175–177.

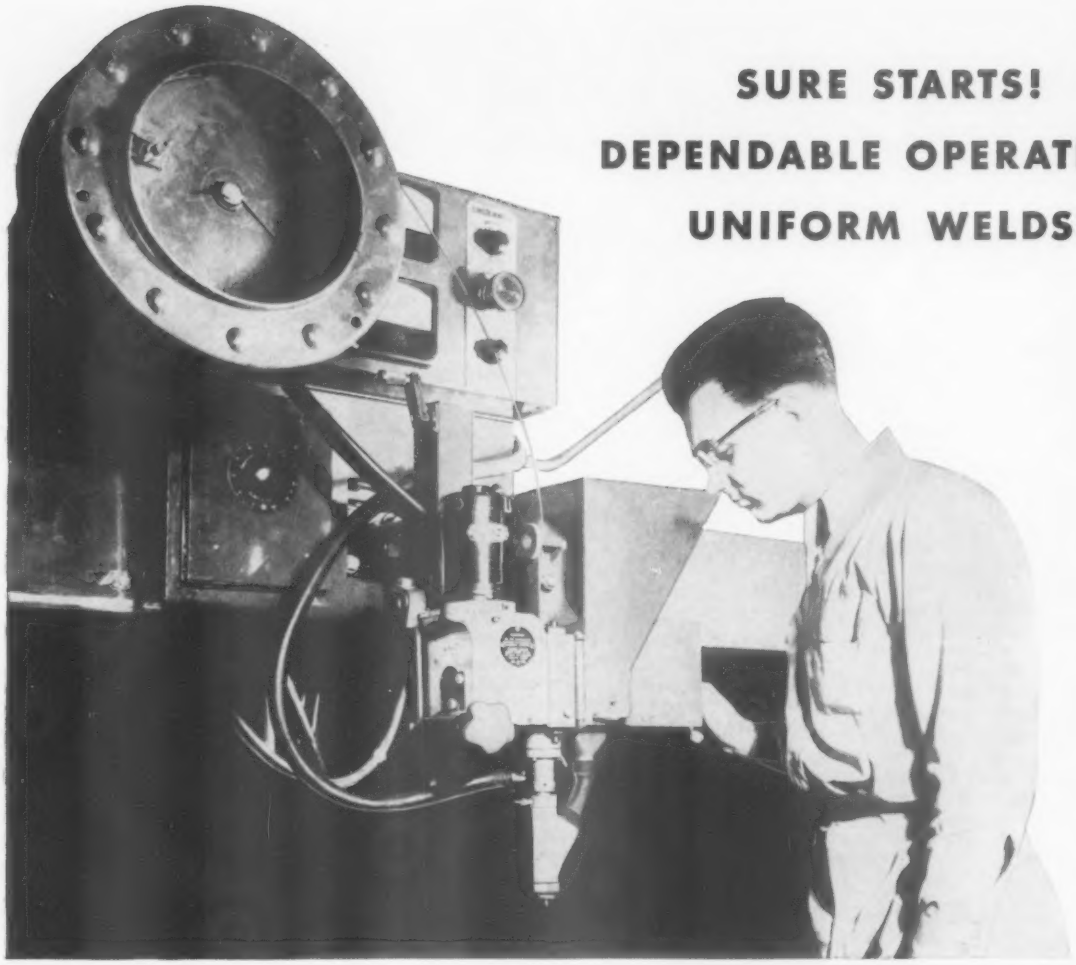
Surfacing. Selection of Hard Facing Materials for Lowest Maintenance Cost, N. D. Berrick. *Australasian Engr.* (Aug. 7, 1956), pp. 47–53.

Tanks. Enough to Make a Russ Turn Red! P. P. Baranovsky and K. I. Vaysberg. *Welding Engr.*, vol. 41, no. 10 (October 1956), pp. 32–33.

Tanks. Failure of Pachuca Tanks of Welded Construction, J. Wallace. *S. African Mech. Engr.*, vol. 5, no. 9 (April 1956), pp. 389–396; (discussion) 396–399, No. 12 (July 1956), pp. 483–486.

Tanks. In Japan—Weldors Erect New T-1 Steel Vessels, J. Fairlie. *Welding Engr.*, vol. 41, no. 7 (July 1956), pp. 30–31.

Testing. Isotope Testing of Welded Seams for High-Pressure Pipelines in Germany, H. H. Loy. *Elec. Light & Power*, vol. 34, no. 7 (Mar. 25, 1956), pp. 107–109, 111.



SURE STARTS!

DEPENDABLE OPERATION!

UNIFORM WELDS!

LINCOLNWELD

Automatic, Submerged Arc Welders

best for automatic production... structural fabrication... hardsurfacing

Write for Bulletin SB-1355 containing specifications and details.

gives you:

- uniform welds under irregular conditions
- choice of cold starts or hot starts
- infinitely variable and reversible inching speeds
- choice of DC, AC or engine driven power sources

easiest to adapt to any fixture.

THE LINCOLN ELECTRIC COMPANY

Dept. 1926, Cleveland 17, Ohio

The World's Largest Manufacturer of Arc Welding Equipment

ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,771,735—"Method of Welding the Ends of a Chain Link Wherein Initial Point Contact is Obtained Between the Ends"—Thomas A. Wilson, Kenmore, Humphrey F. Parker, Buffalo, Raymond J. Kieffer, Tonawanda, and Robert T. Gillette, Scotia, N.Y., assignors to Columbus McKinnon Chain Corp., Tonawanda, N.Y.

This patent is on a method of making a chain link and comprises forming the opposite ends of a length of weldable metal bar into a V-shaped form to present straight edge portions at the end, which portions extend transversely of the bar and lie in separate, substantially perpendicular longitudinal planes. The bar is then bent into looped form and the opposite ends thereof are brought into opposed abutting relation with the straight edge portions disposed in transverse relationship to each other. Thereafter the end portions are subjected to welding temperature while pressed together to deform the V-shaped ends while completing the weldment therebetween.

2,772,345—"Dental Spot-Welder"—Burdett L. Gainsforth, Ogallala, Nebr.

This patent is on a spot-welder having a casing with a welding transformer therein. An upper, stationary electrode is provided on the casing while a platform having a lower electrode attached thereto is also present in the apparatus. The platform is pivotally attached to the casing for swinging movement so as to bring the electrodes into contact with each other and for separating them, as desired. A tap switch is connected in the apparatus between the electrodes and the transformer so that a welding circuit can be closed thereby when the platform is in the electrode contacting position.

2,772,346—"Heat Blasting Tool with Fluid Jet"—Theodore I. Leston, New York, and William B. Kriewall, Flushing, N.Y., assignors to All-Sil Welding Metals, Inc., New York, N. Y., a corporation of New York.

The present patent relates to an electrically operated consumable blasting tool for uses such as boring holes in refractory materials. The tool includes a pair of spaced electrically conductive members embedded in the covering composition of a substantially electrically non-conductive insulatory nature, which covering material includes a substantial portion of iron oxide producing ingredients and gas forming ingredients in mixed granular form. The conductive members are made from an arc consumable material. Means are provided in the tool for directing a stream of electrically conductive expansible liquid between the pair of electrically conductive members to form a series electric circuit therebetween and have a self-sustained electric arc between such members for heating and expanding this liquid as it is discharged from the tool by passing between the conductive members.

2,772,963—"Inert-Gas Shielded-Arc Welding of 90-10 Type Copper-Nickel Material"—George Raymond Pease, Westfield, and Theodore Ephraim Kihlgren, Berkeley Heights, N. J., assignors to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware.

This patent relates to a welding rod having a special composition including specified amounts of copper, nickel, iron, silicon and other materials therein. The rod has a minimum content of lead therein with relation to the amount of silicon present to avoid any appreciable lead contamination in the resultant weld metal.

2,772,989—"Treated Wire for Arc Welding Electrodes"—Edward R. Gamberg, Irwin, and Howard C. Ludwig, Pittsburgh, Pa., assignors to Westinghouse Electric Corp., East Pittsburgh, Pa., a corporation of Pennsylvania.

This patent is on a welding electrode particularly adapted for use in welding in open air. The wire core of the electrode consists essentially of iron and nickel and has on its surface a layer of a dissociable oxygen containing arc stabilizing compound. A flux coating is provided on the surface to prevent oxidation of the weld. Such compound is present in sufficient thickness to stabilize the arc without producing oxidation of the weld.

2,773,169—"Welding of Bladed Rotors for Turbines, Compressors, etc."—George Lees, Leicester, England, assignor to Power Jets (Research and Development) Limited, London, England, a British company.

Lees' patent relates to a method of constructing a turbine-bladed rotor by welding a ring of blades around the rim of the rotor. First the rotor is formed with a plurality of peripheral recesses extending inwardly from one end face thereof and extending to the periphery of the rotor and a second series of like recesses are formed extending inwardly from the other end face in a longitudinal direction. Then the ring of blades is provided so that it can be engaged with these two sets of recesses provided in the opposite end faces of the rotor. The ring of blades is brought into engagement with the rim of the rotor and the recesses therein and then the blades exposed on one end face of the rotor are welded in place after which the blades positioned in the recesses formed in the other rotor end face are welded in position to complete the rotor construction.

2,773,170—"Attachment for Welding Machines"—Julius A. Barthel, Milwaukee, Wis.

Barthel's patent relates to an attachment for an electric welding machine for stabilizing the welding arc. The attachment comprises a case having a plurality of capacitors therein. Means are provided for selective engagement with different ones of the capacitors for positioning them in parallel with the welding arc.

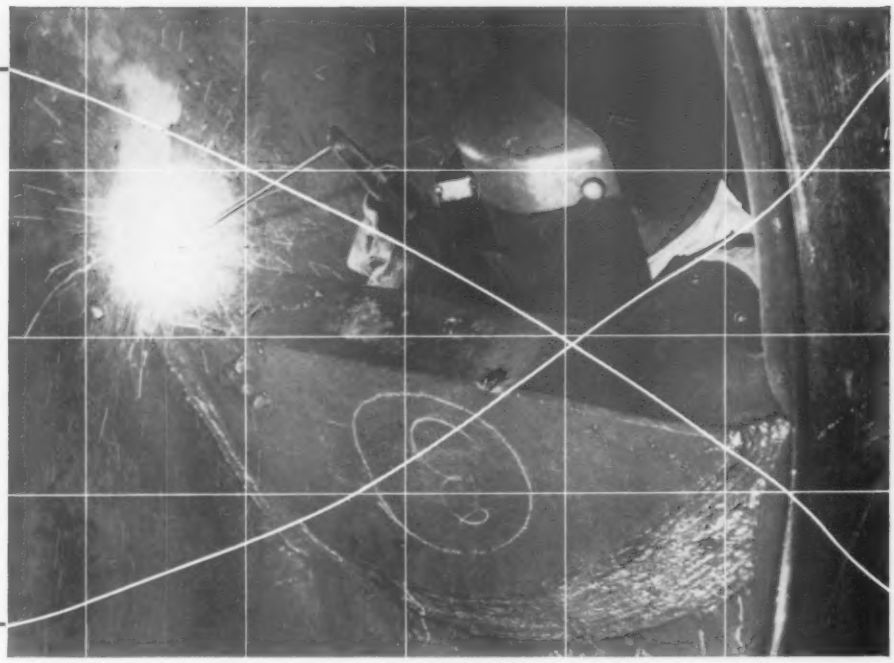
2,773,969—"Device for Producing Auxiliary Magnetic Fields in Electric Arc Welding"—Hans Gunther, Mosbach, Baden, Germany, assignor to Kraftanlagen A.G., Heidelberg, Germany.

This patent relates to specialized welding apparatus including a pressure block of non-magnetizable material which is positioned transversely across an electrode that is positioned substantially parallel to a desired welding joint and in contact therewith. The pressure block is spaced from the work on both sides of the electrode to provide an open gap between the work and pressure block. A magnetic field generating means is provided to establish a field extending transverse to the electrode and in a direction to deflect the arc and the molten material towards the work. A positioning means forces the pressure block towards the electrode and positions the electrode with respect to the work.

2,773,970—"Metal Arc Welding Apparatus"—John F. Galbraith, Plainfield, Wilbur H. Helmbrecht, Union, and Roscoe R. Lobosco, Fanwood, N. J., assignors to Union Carbide and Carbon Corp., a corporation of New York.

Metal arc welding apparatus is covered in the patent and such apparatus includes an ac-dc rectifier source of welding current adapted to have an open-circuit potential of between about 15 and 45 volts. The welding operation is stabilized by making the rectifier source provide a welding current having a drop of not more than one volt per 50 amp increase in welding current.

Maintenance Cost Down



Equipment Service Life Up

NEW IRON POWDER HARD SURFACING ALLOYS
INCREASE DEPOSITION RATES — EXTEND PART LIFE

Longer wearing deposits and shorter down time increase efficiency of maintenance.

Every consumer of hard surfacing and build-up alloys desires an electrode having faster deposition rates and longer wearing deposits in order to shorten down time and increase overall operating efficiency. Here are three *new* iron powder hard surfacing electrodes designed to provide economies and quality of weld metal never before possible in hard surfacing operations.

Faster Deposition Rates

Because of the iron powder in the coating, higher welding currents may be used, thereby depositing more pounds of weld metal per hour. Greater deposition efficiencies are achieved because the iron powder serves as an additional source of weld metal.

Longer Wearing Deposits

Most hard facing alloys dilute heavily with the base metal on the first pass because of penetration. Although higher currents are used with these iron powder alloys, there is actually less penetration of the base metal because the added electrical energy is consumed in melting the iron powder rather than in disturbing the base metal. This provides a dense, porosity free higher alloy deposit ensuring longer part life.

Greater Ease of Application

Weldors will enjoy the smooth, easy to control arc characteristics of these new iron powder alloys. Spatter is practically eliminated and weldor fatigue is lessened to a point where you will see the gain in pounds of weld metal deposited.

Wear-Arc 3—I. P.

An iron powder low hydrogen build-up alloy for all weldable grades of carbon steel. This alloy has outstanding physical properties and provides an excellent base for hard surfacing deposits.

Wear-Arc 6—I. P.

An iron powder low hydrogen hard surfacing alloy for all position application. Designed for resistance to wear caused by severe abrasion in combination with heavy impact.

Wear-Arc 12—I. P.

An iron powder low hydrogen hard surfacing alloy for resisting wear caused by severe impact and abrasion.

Wear-Arc Iron Powder to be introduced and demonstrated live for first time at AWS Show . . . Booth 101—April 9, 10, 11, Convention Hall, Philadelphia, Penna. If you rebuild or hard surface worn equipment parts, Booth 101 will be your most profitable "spot" at the show.

Alloy Rods Co.

General Offices and Plant
Lincoln Highway West
YORK 3, PENNSYLVANIA

Pacific Coast Sales Office and Plant
750 Lairport Street
EL SEGUNDO, CALIF.

NO FINER ELECTRODES MADE . . . ANYWHERE

NEWS of The Industry

Linde Unveils New Arc-Welding Process

Magnetic-flux gas-shielded arc welding, a new process for the manual welding of mild steel, was demonstrated by the Linde Air Products Co. at an editor's meeting held in Newark, N. J., on Jan. 22, 1957. It will be shown publicly on April 9th at the AMERICAN WELDING SOCIETY Show in Philadelphia.

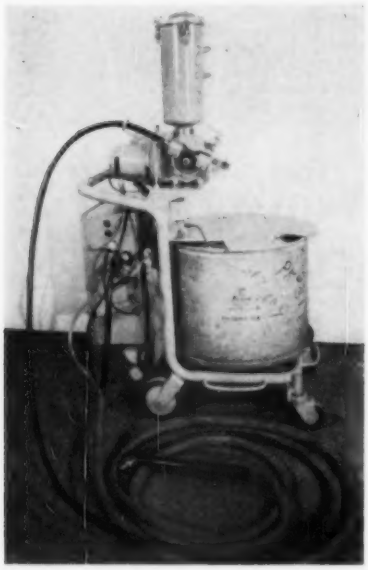


Fig. 1 Side view of semiautomatic machine for magnetic-flux gas-shielded arc welding showing wire supply mounted on rotating assembly. This machine may be used for welding in flat, vertical, overhead or horizontal positions

Marketed under the trade name of "Unionarc" welding, the process embodies the following concept—a continuously fed wire electrode which is magnetically coated with flux and shielded in a gas atmosphere. At the present time, the process is being applied principally to steel. It can be used in all positions.

In magnetic-flux gas-shielded arc welding, a bare wire electrode of common steel composition is continuously fed from a 300-lb-capacity pack through a flexible tube to the torch. The operator starts and continues welding to suit his requirements. There is no frequent stopping to change

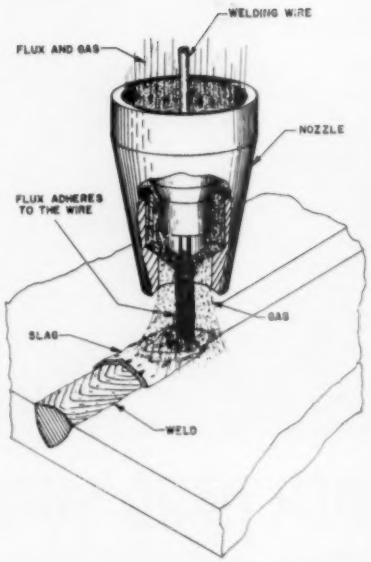


Fig. 2 Cutaway sketch of nozzle showing the basic factors involved in magnetic-flux gas-shielded welding

electrodes nor a series of starts and stops in making a joint. The wire is supplied in a "pay-off pak," covered to keep the wire clean. The pack is supported and rotated on a motor-driven turntable, controlled so that wire tension at the feed rolls is minimized. The large wire pack provides at least one week's supply with average welding conditions.

A magnetizable flux is placed in

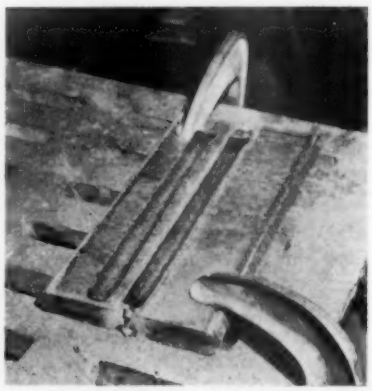


Fig. 3 A completed weld in ¾-in. plate shows the appearance of joints made with the magnetic-flux gas-shielded process. The fused flux is easily removed, as shown at the left of the weld

a dispenser and fed from this point through a flexible tube to the torch. The dispenser is designed to measure exactly the amount of flux in proportion to the amount of wire that is being fed. The dispenser can be adjusted to feed different flux-to-wire ratios, but the usual ratio is between $^3/_8$ to $^1/_2$ lb of flux per pound of wire. This predetermined ratio is automatically maintained regardless of the rate of wire feed.

The flux is fluidized at the dispenser in a stream of welding-grade carbon dioxide gas. The gas, supplied from the usual commercial containers, is regulated as to pressure and flow and carries the flux to the torch suspended in the gas stream.

At the torch nozzle, the magnetic field created by the electric current passing through the wire, magnetizes and attracts the flux to the wire. As a re-

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1957 Spring Meeting and Welding Show:

April 8–12, Hotel Sheraton, Philadelphia, Pa.

April 9–11, Fifth Annual Welding Show, Convention Hall, Philadelphia, Pa.

ASM

March 25–29, Tenth Western Metal Congress and Exposition, Los Angeles. Congress at Ambassador Hotel; exposition in Pan-Pacific Auditorium.

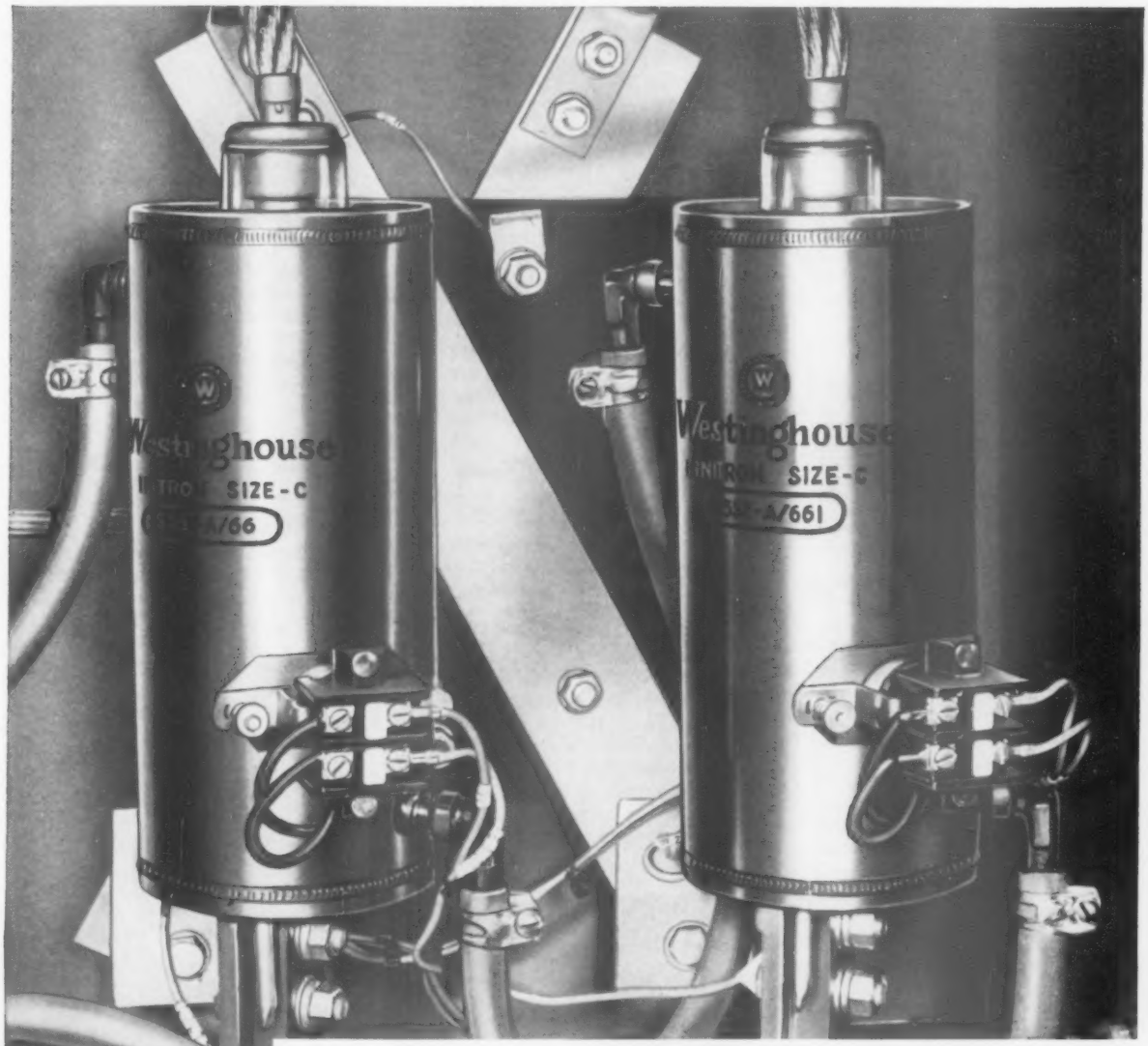
IAA

April 1-3, Fifty-seventh Annual Convention, Hotel Nicollet, Minneapolis, Minn.

NWSA

May 13–16, Thirteenth Annual Convention, Hotel Mayflower, Washington, D. C.

Westinghouse **IGNITRON TUBES** still the industry standard.



Westinghouse invented the Ignitron tube and has maintained a record of improvements that are today the accepted industry standards:

- kovar seals to permit use of steel envelopes
- improved ignitors to assure accurate ignition.
- thermostatic control for overload protection and water savings.

For highest quality Industrial and Special Purpose tubes—always specify Westinghouse.

YOU CAN BE SURE... IF IT'S Westinghouse

7ET-4103

THERMO Spiral

—the ONLY Tip Cleaners that GUARANTEE These OUTSTANDING Advantages

- Accumulated carbon and slag removed without scratching or enlarging orifice.
- Left-hand spiral ridges clean and burnish old tips to **new** tip efficiency.
- Have no breakage points caused by grooves running horizontally.
- It's the ONLY Tip Cleaner with uniformly rounded cleaning ridges.
- Locked in compact case to prevent damage. Standard set of 12 cleans 27 drill sizes.
- Send for a FREE THERMO Spiral Tip Cleaner TODAY and prove to yourself it can't be broken in normal use.

All Progressive Welding Supply Dealers stock THERMO Tip Cleaners

THERMACOTE Company

108 S DeLacey Ave.
PASADENA, CALIFORNIA

sult, the wire is "coated" as it is fed into the arc. The flux melts and does four important jobs: (1) together with the shielding gas, it stabilizes the arc and the stream of molten metal passing through it to the puddle, and protects the puddle from atmospheric contamination; (2) it refines the molten metal by deoxidation; (3) it provides the desired control of weld contour by its effect on surface tension; and (4) it provides the desired cooling rate of the weld metal by its blanketing and insulating action.

The welding current is supplied by a direct-current power source. A constant potential rectifier can be used with the added advantage of assuring easy and uniform starting and control of arc length.

The arc characteristics of magnetic-flux gas-shielded welding are described as being similar to those of covered-electrode welding. Under most welding conditions, metal transfer is "spray-type," and very little spatter is evolved. The small amount of spatter produced by this process is not tenacious, and can be readily removed by wiping or light brushing.

The welding techniques used with the new welding process are comparable to those employed with the most commonly used covered electrodes. Reportedly, after a few hours practice, an operator familiar with covered electrode welding can produce excellent welds. Manual skill and dexterity requirements are said to be equivalent to, or are less than, those for covered-electrode welding.

The sequence of starting and stopping the flow of current, wire, flux and gas, as well as maintaining proper welding conditions, is regulated through an electronic control unit.

Data released by Linde indicate that magnetic-flux gas-shielded arc welding deposits weld metal at a rate that is 50 to 100% greater than that obtained with covered electrodes on the most common downhand welding applications. In the vertical and overhead positions, its deposition rate is two to three times as great as that of covered electrode welding. Moreover, since the process utilizes a continuously fed electrode, the operator can devote more time to actual welding. The higher operating factor, in combination with greater welding speeds, is said to reduce significantly unit labor and overhead costs.

Magnetic-flux gas-shielded arc welding can be used to weld across gaps and along seams containing moderate amounts of rust, scale and moisture without effect on weld soundness.

Executives Appointments Made by Arcos

Royal D. Thomas has been appointed chairman of the Board of the Arcos Corp., Philadelphia, manufacturer and distributor of arc welding rods and electrodes.

His appointment is announced along with that of three other top company officers, all of whom assumed their new posts on Jan. 1, 1957. Mr. Thomas was president of the company since 1937.

Succeeding him as president is R. David Thomas, Jr., who was formerly executive vice-president. James E. Norcross, former general sales manager, becomes executive vice-president.

Royal D. Thomas

R. D. Thomas, Jr.

Henry A. Molt, former works manager, assumes the new office of vice-president in charge of manufacturing.

The Messrs. Thomas, Thomas, Jr., and Norcross are members of the AMERICAN WELDING SOCIETY.

Eutectic Names Two New Directors

Two vice-presidents at Eutectic Welding Alloys Corp. have been elected to the Board of Directors, Rene D. Wasserman, president, has announced.

They are Fred F. Roehll, vice-president and national sales manager, and Joseph F. Quaas, vice-president in charge of manufacturing and production. The election brings to six the number on the Board.

Fred F. Roehll

Mr. Roehll joined the company in 1946 and was named a vice-president in 1953. Mr. Quaas was appointed a vice-president earlier this year after more than seven years' service with the company.

M&T Opens Sales Office in Houston

Metal & Thermit Corp., New York, announces the opening of warehousing and sales office facilities at Houston, Tex.

A complete stock of arc-welding electrodes, including mild and alloy steel, stainless steel and a new line of iron-powder hard-surfacing rods, will be maintained at the Houston Terminal Warehouses, 701 N. San Jacinto St., Houston, with offices at the same location.

John A. Watson, Jr., will be in charge of the operation.

Seattle Expansion for Air Reduction Pacific

An increase in the capacity of the air separation plant at Seattle of the Air Reduction Pacific Co., a division of Air Reduction Co., Inc., has been announced by H. P. Etter, president of the West Coast Co. The increase will triple the current capacity of the Seattle plant and will be completed by the end of April.

The Airco Pacific plant presently produces gaseous oxygen and nitrogen. With the addition of the new facilities the plant will be capable of producing liquid as well as gaseous oxygen and nitrogen. Gaseous argon will also be produced.

The Seattle district of Air Reduction Pacific Co. is under the supervision of L. A. Hamilton, vice-president.

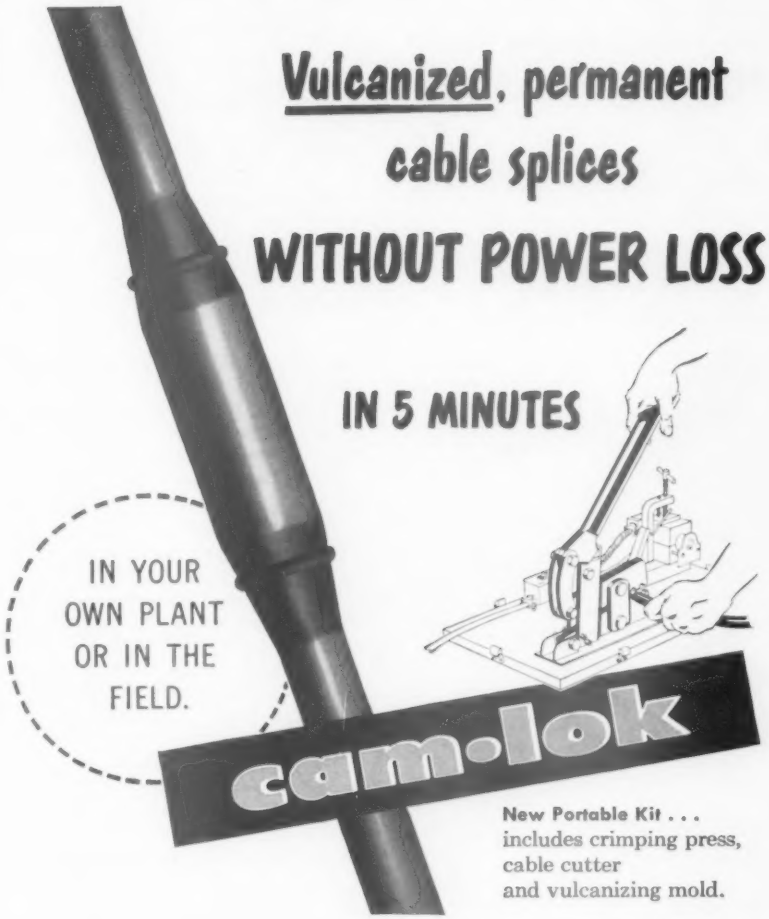
NCG to Build and Expand Plants

A program for construction of industrial gas production facilities or expansion of present facilities at six locations in Alabama, California, Illinois, Puerto Rico and Venezuela has been announced by the National Cylinder Gas Co.

The expansion program will bring to 78 the number of plants at which NCG produces one or more kinds of industrial gas, including one in Canada, another in Puerto Rico, three in Colombia and five in Venezuela.

Charles J. Haines, president, said in Chicago recently that a $3,000,000 addition to NCG's liquid oxygen plant in Chicago will increase that plant's output by 150%. This plant, which also produces nitrogen and argon, was completed in March 1955 at a cost of $3,500,000 and is operating at full capacity. Equipment for the Chicago addition has been ordered and construction is expected to be completed in the summer.

National Cylinder Gas Co. is also completing construction of a plant at



New CAM-LOK portable Cable Splicing Kit produces vulcanized, neoprene insulated cable splices anywhere in just 5 minutes . . . makes them waterproof, shockproof.

Simply strip back insulation on cables . . . insert bare ends in copper tube supplied . . . crimp . . . place inner sleeve over crimp . . . vulcanize outer sleeve to cable jackets. No tools or experience needed . . . no production delays.

- Insulating sleeves are vulcanized to cable . . . can't pull away . . . prevents moisture from entering and damaging cable.
- Conductivity of splice is as good as the cable itself. Cables are crimped under great pressure into a pure copper crimping tube.
- Completed splice is tapered and only slightly larger than cable, so cable won't be caught on obstructions when dragged.
- Economical . . . because of low cost of components . . . allows you to splice as little as two, 2′ sections together, which might otherwise be wasted.
- Splice is flexible, because inner sleeve eliminates voids or weak spots in the insulation.
- Finished insulation of splice will withstand 2,500 volts without any leakage.

Write for Catalog and full details today, or see the complete CAM-LOK line in Booth #440, AWS Welding Show, April 9-11, Philadelphia.

CAM-LOK Division
Empire Products, Inc.
P. O. Box J-98, Cincinnati 36, Ohio

Here's Just 3 Reasons Why So Many Welder's Have Switched

- Wrap around Glass Fibre Tip Insulation—30% *more* heat resistance than any other make!
- Brilliant Red Tips and Trigger—Bright Yellow Handle—all Glass Fibre, an outstanding Safety Feature!
- Body completely insulated—no bare spots!

HI-AMP®
ELECTRODE HOLDERS
are the most economical to buy and maintain too!

Will see you at A.W.S. in Philadelphia April 9–11, our Booth 107.

LENCO, INC.
(Formerly Wagner Mfg. Co. Inc.)
JACKSON, MISSOURI

Weld with HI-AMP

San Leandro, Calif., to begin production of oxygen early this year to supply San Francisco area industries.

A new hydrogen compressing plant at Huntsville, Ala., is scheduled to start production this month to meet industrial demands for electrolytic hydrogen for the processing of metals.

At San Juan construction will start this month on an oxygen and acetylene producing plant to serve a steel mill and other consumers in expanding Puerto Rican industry.

In Venezuela, equipment has been ordered to double capacity of the NCG oxygen plant at Maracay, and the company is constructing a new oxygen plant at the iron ore mine port of Puerto Ordaz.

Linde Sponsors Welded Sculpture

Linde Air Products Co. established a $300 award for the best sculpture produced by oxyacetylene welding and cutting entered in the 1957 Chicago Artists Exhibition held Feb. 12–26 at Navy Pier. The purpose of Linde's Prize was to stimulate interest in the versatility of the oxyacetylene flame as a means of shaping and joining metals. Selection of the award-winning entry, as yet unannounced, was made by an independent art jury of recognized competence. A Linde representative served as technical advisor to the jury.

Entries for the exhibition were open to sculptors over 18 years of age living in Illinois within 100 miles of Chicago. Sculpture was limited to 7 ft in height and 1000 lb in weight.

Electronic Welding Co. Established

A contract welding facility has been established at 1209 Chestnut St., Burbank, Calif., under the management of George Palmer. The firm is known as Electronic Welding Co.

Mr. Palmer is a graduate in electrical engineering from Columbia University. His experience includes four years as a welding engineer for Grumman Aircraft, Long Island, N. Y.; 11 years as district manager for Sciaky Bros., manufacturers of resistance welding equipment; two years as a consulting engineer; and one year as distributor and consulting engineer involving instrumentation and accessories for welding machines.

Mr. Palmer is a member of the AMERICAN WELDING SOCIETY.

Field Vice-Presidents Named by Airco

It has been announced that three regional vice-presidents have been named by Air Reduction Sales Co. to administer field activities pertaining to production, distribution and sales, effective Jan. 1, 1957.

A. C. Brown, Jr., general sales manager, was named vice-president, Eastern Region, with offices in New York City; D. D. Spoor, equipment sales manager, New York, has been appointed vice-president, Midwestern Region, and will be located in Chicago, Ill.; and J. J. Lincoln, Jr., vice-president, New York, will become vice-president, Southern Region, with headquarters in Houston, Tex.

Mr. Spoor joined Air Reduction in 1928 as plant superintendent in Sacramento, Calif. He held numerous sales posts in Philadelphia, New York and St. Louis from 1930 to 1941. He was appointed manager of the St. Louis district in 1941. In 1944 he was named manager of the dealer sales department, New York, and four years later was appointed manager of equipment sales. Mr. Spoor was on a one-year leave of absence during which time he served with the government's National Production Authority in Washington, D. C., representing the welding industry. He returned to his post of equipment sales manager in 1952, a position he has held up to this time.

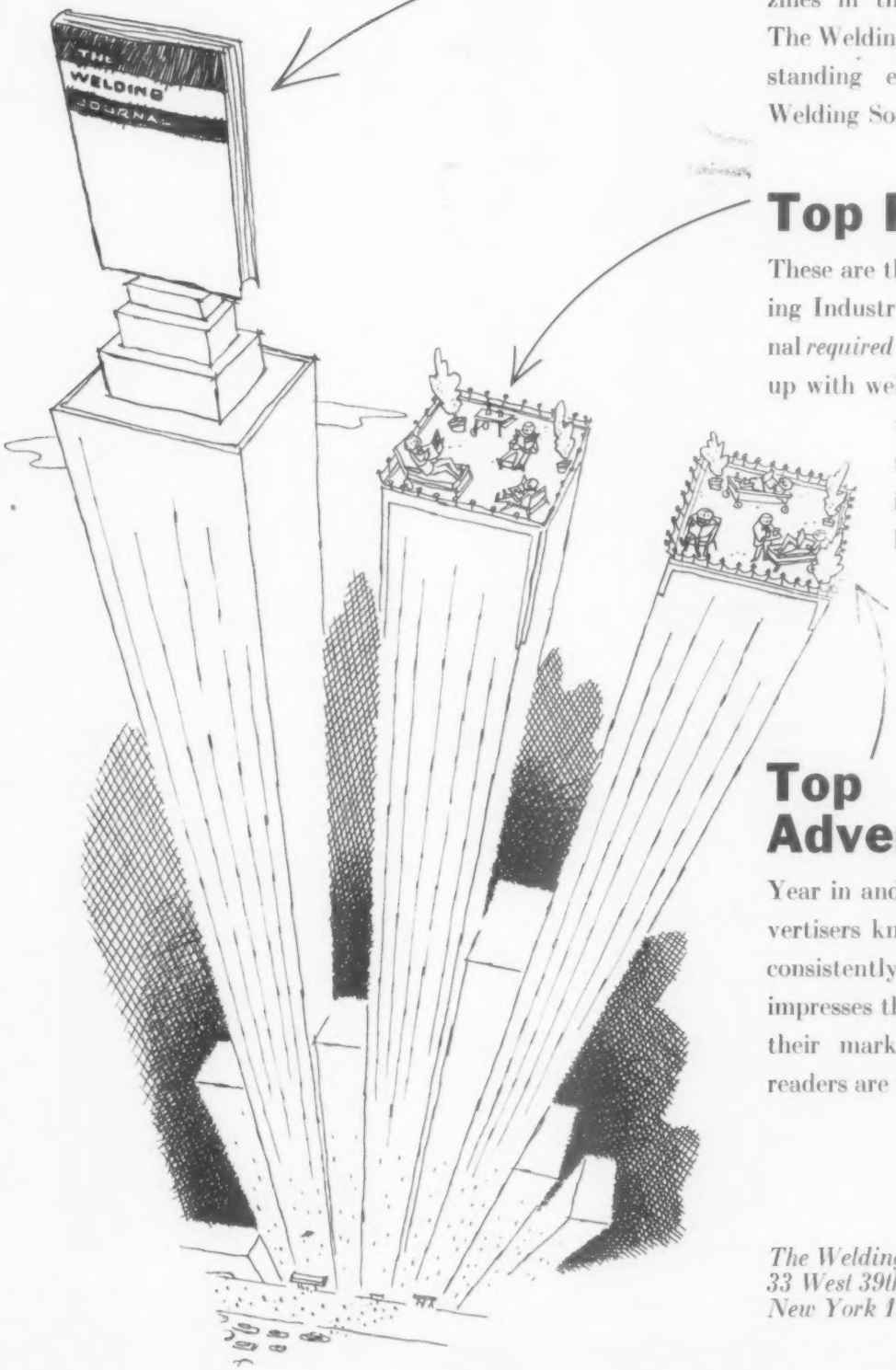
A. C. Brown, Jr.

Mr. Lincoln joined Air Reduction in 1924 and held various sales positions in New York, Pittsburgh and Cleveland.

D. D. Spoor

In 1929 he was appointed district manager at Bettendorf, Iowa, and in 1931, sales manager at Pittsburgh. He was appointed sales manager of the South Central Region in 1939 and in 1945 was named director of sales, New York.

J. J. Lincoln



Top Magazine!

Yes. . .far and above other magazines in the welding industry is The Welding Journal. . .whose outstanding editorial content and Welding Society news are read by

Top Readers!

These are the leaders in the Welding Industry who make the Journal *required reading* in order to keep up with welding developments. . . the executives who do the buying and specifying. . .with tremendous loyalty to the Journal's

Top Advertisers!

Year in and year out, Journal advertisers know that their message consistently reaches, informs, and impresses the people who make up their market. Welding Journal readers are worth knowing!

The Welding Journal
33 West 39th Street
New York 18, N. Y.

Mark Your Calendar
April 9–11, 1957
FIFTH AWS WELDING SHOW
and
April 8–12, 1957
AWS ADAMS
NATIONAL MEETING
Philadelphia, Pa.

In 1949 Mr. Lincoln was made vice-president of railroad sales and sales services, and in July of 1956, vice president—assistant to the president, New York.

Mr. Brown joined Air Reduction in 1935 at the Cleveland sales office. From 1938 to 1940 he was attached to the Detroit sales office and from 1940 to 1941, he was in Airco, Grand Rapids. In 1946, after five years in the Army, Brown rejoined Airco at the Cleveland office as assistant manager. Shortly thereafter he was appointed manager at Cleveland. He was appointed regional manager of the central region in 1950 with headquarters in Pittsburgh. In 1953 he was named general sales manager, New York, the position he has held up to this time.

The Messrs. Spoor, Lincoln and Brown are members of the AMERICAN WELDING SOCIETY.

Wolfenden Wins Award

Wolfenden Welding Supplies, Inc., 3500 Prospect Ave., Cleveland, Ohio, for the second consecutive year has achieved the distinction of finishing in first place among Hobart Bros.' distributors competing in the "Volume Sweepstakes" for 1956. On Jan. 8, 1957, the company was cited for its outstanding work in building sales for welding equipment, electrodes and accessories, giving them the largest volume of business of any Hobart distributor.

Volume Sweepstakes award for 1956 is presented to Wolfenden Welding Supplies, Inc., by E. A. Hobart, president of Hobart Bros. Co. (*Left to right*) Bill Wolfenden, John T. Wolfenden, Jr., and Mr. Hobart

Second place went to H. K. Miller, Inc., Chicago, Ill., and third place to Roy Smith Co., Detroit, Mich. Hobart "Quotabusters" awards went to Oxygen Service Co., Kingsport, Tenn., for first place; Andries Welding Supply Co., Jackson, Miss., for second place; and Harry's Equipment Rentals, Jacksonville, Fla., for third place.

Executives Promoted by Smith Welding

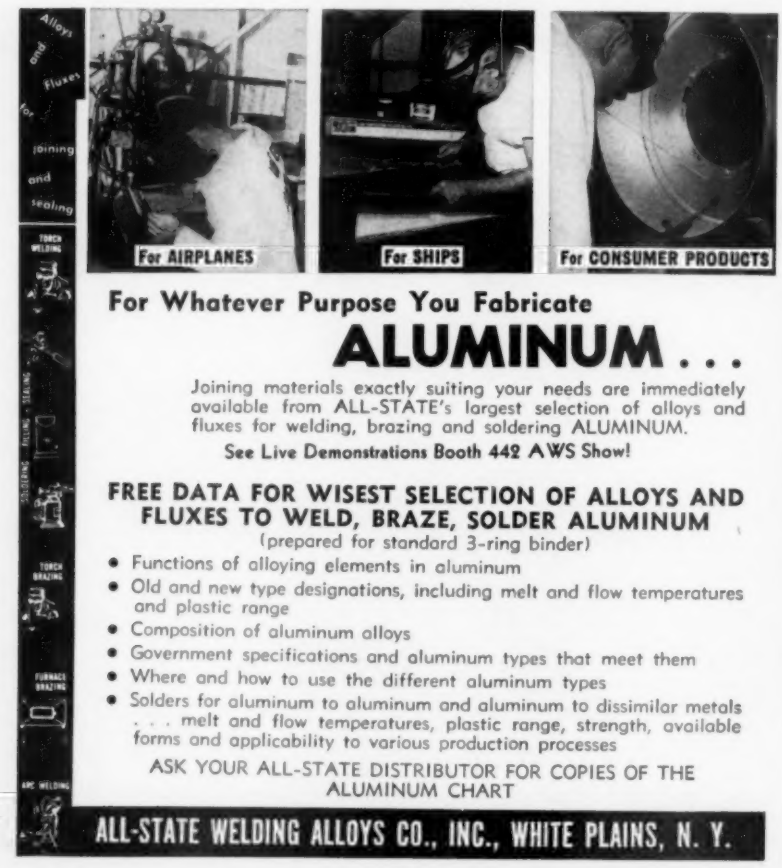
Lloyd L. McBurney, president of Smith Welding Equipment Corp., Minneapolis, has announced two executive advancements.

Jack E. Smith

Jack E. Smith, vice-president and formerly in charge of production and engineering, will be vice-president and manager of the newly created Research and Development Department.

Percy E. Taylor

Percy E. Taylor, formerly personnel manager of the company, has been appointed manager of production and personnel.



For Whatever Purpose You Fabricate

ALUMINUM . . .

Joining materials exactly suiting your needs are immediately available from ALL-STATE's largest selection of alloys and fluxes for welding, brazing and soldering ALUMINUM.

See Live Demonstrations Booth 442 AWS Show!

FREE DATA FOR WISEST SELECTION OF ALLOYS AND FLUXES TO WELD, BRAZE, SOLDER ALUMINUM

(prepared for standard 3-ring binder)

- Functions of alloying elements in aluminum
- Old and new type designations, including melt and flow temperatures and plastic range
- Composition of aluminum alloys
- Government specifications and aluminum types that meet them
- Where and how to use the different aluminum types
- Solders for aluminum to aluminum and aluminum to dissimilar metals . . . melt and flow temperatures, plastic range, strength, available forms and applicability to various production processes

ASK YOUR ALL-STATE DISTRIBUTOR FOR COPIES OF THE ALUMINUM CHART

ALL-STATE WELDING ALLOYS CO., INC., WHITE PLAINS, N. Y.

Makes reading easier... quicker

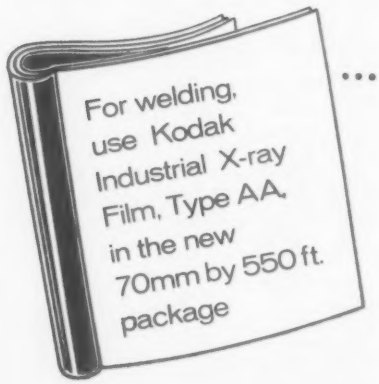
Kodak Industrial X-ray Film, Type AA, gives you greatly increased speed — a film characteristic that brings the radiographer greatly extended possibilities.

As an example: by using reduced kilovoltage and usual exposure time, greater radiographic contrast and easier readability are obtained.

In addition to ranging up to double the speed, this new film retains the fine sensitivity characteristics which made Kodak Type A the most widely used x-ray film in industry.

Kodak Industrial X-ray Film, Type AA, can save you time and extend the usefulness of your present radiographic equipment. Get all the details. Contact your x-ray dealer or Kodak Technical Representative.

EASTMAN KODAK COMPANY, X-ray Division
Rochester 4, N. Y.

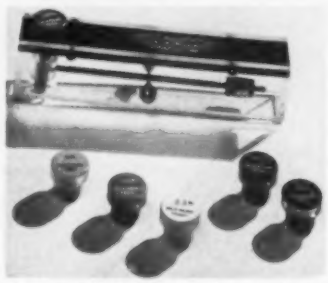


Read what the new Kodak Industrial X-ray Film, Type AA, does for you:

- Reduces exposure time—speeds up routine examinations.
- Provides increased radiographic sensitivity through higher densities with established exposure and processing technics.
- Gives greater subject contrast, more detail and easier readability when established exposure times are used with reduced kilovoltage.
- Shortens processing cycle with existing exposure technics.
- Reduces the possibility of pressure desensitization under the usual shop conditions of use.

Kodak
TRADE MARK

FERRITE INDICATOR



Ferrite Indicator is a simple, rugged, nondestructive inspection instrument developed for laboratory, shop, and field use. Go no-go feature permits instant acceptance testing of austenitic stainless and manganese weld and base metals. Requires no external standards, no adjustments, no visual readings, and is unaffected by position. Performs equally well on sheets, plates, rods, irregular shaped objects, and individual parts of complex components. Effective in locating areas of high and low ferrite content in heterogeneous products.

- Indicator covers all practical welding requirements; inserts being available in the range of 1.5% to 15% ferrite.
- Indicator weighs but three ounces and is 5" long. All metal components are bright nickel plated and the Indicator is furnished in a handsome hardwood box.

Write today for complete details.

Severn

Engineering Company, Inc.

Mfrs. Ferrite & Permeability Indicators

P. O. Box 944 **Annapolis, Maryland**

Airco Expands Facilities at Butler

An increase in the capacity of the air separation plant at Butler, Pa., a facility of the Air Reduction Sales Co., a division of Air Reduction Co., Inc., has been announced. The increase, which will double the capacity of the Butler plant, will become effective on January 1st.

The Butler plant produces liquid and gaseous oxygen, nitrogen and argon. It began operation in November of 1952, and is under the supervision of G. A. Benz, works manager.

Steel Plate Fabricators Elect Michaels President

At the 24th annual meeting of the Steel Plate Fabricators Assn., held at the Palmer House in Chicago on January 17th and 18th, Ernest E. Michaels, president of Chicago Bridge & Iron Co., was elected president of the Association. He is a member of the AMERICAN WELDING SOCIETY.

Other officers elected were vice-president, Walter B. Van Wart, president, Wyatt Metal and Boiler Works, Houston, Tex.; treasurer, Otto H. Lange, Hibben & Co., Chicago; executive director and secretary, J. Dwight Evans, Steel Plate Fabricators Assn.

New regional vice-presidents elected were: Western—J. C. McPherson, Consolidated Western Steel; Eastern—J. E. Jackson, Pittsburgh-Des Moines Steel Co.; Southeast—J. T. Barriger, W. E. Caldwell Co.; Southwest—B. B. Basom, Kansas City Structural Steel Co.

The Steel Plate Fabricators Assn., which is a nonprofit organization, was organized in 1934. It has as its main objective the advancement of a stable but progressive steel plate fabricating industry. The leading steel plate fabricators, with plants located in the main industrial areas of the United States and in many other parts of the world, are represented by the Association.

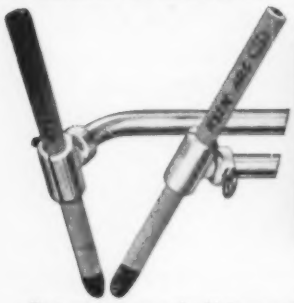
Eutectic Opens Warehouse in Phoenix

A new Eutectic Welding Alloys Company of Arizona, Inc., Warehouse-Service Center, has opened at 1402-1414 S. Seventh St., Phoenix. It will be supervised by John Maffeo, a long time Phoenix resident and businessman.

Other Eutectic Warehouse Service Centers are situated in New York, Chicago, Atlanta, Dallas, Berkeley and in Montreal, Canada.

BECKER

KEEN-ARC CARBONS



FOR CONSISTENTLY GOOD RESULTS

Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends—eliminates frequent and periodic resetting.

A COMPLETE LINE OF CARBON WELDING SUPPLIES including carbon and graphite electrodes, carbon rods and plates, welding paste, etc.

Write for catalog.

BECKER BROTHERS CARBON CO.

3450 South 52nd Ave. Cicero 50, Illinois

EXCELLENT OPPORTUNITY FOR EDITORIAL ASSISTANT-SPACE SALESMAN

National engineering society monthly requires resourceful, capable assistant to sell advertising space and to aid with overall editorial and production activities. Field closely allied to metallurgy and metal fabrication. In reply, please outline experience, personal history and salary requirements. Box V-337.

Advertising Rates

The Welding Journal

Effective June 1, 1953	1 time	3 times	6 times	12 times
Full Page	$305.00	$280.00	$265.00	$240.00
Two-thirds Page	215.00	200.00	185.00	175.00
Half Page	170.00	155.00	145.00	130.00
One-third Page	125.00	115.00	110.00	105.00
Quarter Page	100.00	95.00	90.00	85.00
One-sixth Page	75.00	70.00	65.00	58.00
Eighth Page	62.00	58.00	50.00	46.00
Special Preferred Positions: (Full Page)	335.00	310.00	295.00	270.00
COVERS 12-time contracts only:				
2nd cover				300.00
3rd cover				275.00
4th cover				325.00

Welding Progress

© METAL & THERMIT CORP. 1957

at METAL & THERMIT CORPORATION • General Offices: Rahway, N. J.

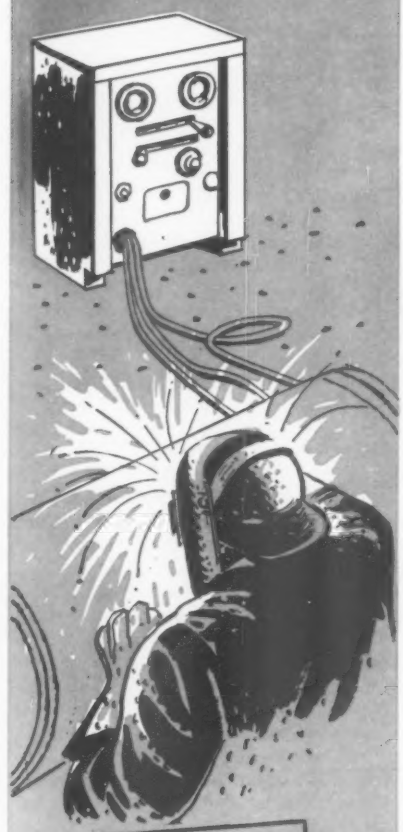
CONTROLLED ARC POWER SUPPLY ADVANTAGES FOR SEMI-AND AUTOMATIC WELDING TO BE DEMONSTRATED

New M&T welder eliminates variables in operation, lowers costs, improves quality.

"Live" demonstrations of Metal & Thermit's new Controlled Arc Power Supply for constant voltage welding will be the focal point of this year's M&T exhibits at the Western Metal Exposition in Los Angeles March 25-29, and also at the AWS show in Philadelphia April 9-11.

This rectifier-type machine delivers DC welding current at constant preset voltages. The demonstration will show how the Controlled Arc Power Supply teamed with a constant speed wire feed automatically controls the arc maintaining a constant arc length. A built in Arc Characteristic Controller provides a "cushion" effect, particularly desirable in low current density welding, and permits a greater range of current density with a given electrode. The result is lower cost, higher quality weldments.

C.A.P.S. welders have an efficiency of 85% or better and a power factor of 90% or higher at all settings. The equipment is rated at 100% duty cycle. Lighter and easily installed input wiring and switching are possible, since less input and current is required than in conventional power sources. Installation and power costs are both appreciably lower. These and other advantages of the C.A.P.S. welder may be discussed with representatives at the Metal & Thermit booth.



VISIT THE METAL & THERMIT BOOTH #508 AT THE 5TH AWS WELDING SHOW

Sponsor: American Welding Society, Inc.

April 9-11, '57
CONVENTION HALL
PHILADELPHIA, PA.

WELDING SUPPLIES • RADIOGRAPHIC EQUIPMENT
PLATING MATERIALS • ORGANIC COATINGS
CERAMIC MATERIALS • TIN & TIN CHEMICALS
METALS & ALLOYS • HEAVY MELTING SCRAP

Low hydrogen coatings improve hard surfacing electrodes

A new and different approach has been made to improve the quality and wearing characteristics of hard facing overlays. Low hydrogen coatings adapted to Metal & Thermit's HARDEX line enable these electrodes to deposit a weld metal of far less porosity and greater freedom from cracking. Penetration into the base metal and dilution by the base metal are at a minimum.

The wide line of HARDEX electrodes enables the welding engineer to select the *one* electrode which provides the best wearing quality at the least cost per pound of metal deposited. An M&T catalog, HS-56, is available through any M&T representative to simplify the selection of the right HARDEX electrode for any one of hundreds of applications.

New chrome-moly electrodes approved

For years one of the nation's foremost producers of power piping and high pressure boilers has been using a specially developed chrome-moly electrode on high pressure — high temperature service equipment. Its outstanding stress-rupture characteristics, high ductility over a wide range of temperatures, and economic advantage over other electrodes has proven the answer to safe, crack-free welds wherever high pressure—high temperature service is required.

Since these electrodes were first introduced by Metal & Thermit under the name Murex® CROLOY, more than half of the country's top petroleum refineries have approved their use for fabricating critical service equipment used in high pressure, high temperature operations. Welding engineers in other industries, too, are finding more and more use for CROLOY on other difficult-to-weld steels. A folder on M&T CROLOY electrodes and how to use them may be obtained through any Metal & Thermit representative.

INTERNATIONAL WELDING NEWS

Welding Research in the Soviet Union

Translation from the German
by Rudolph O. Seitz

Introduction

In recent months there have been a number of reports from delegations visiting Russia about the determined efforts of the Soviet government to catch up with the most advanced Western nations and, finally, to overtake them in the fields of science and engineering. Unfortunately, little has been said about Russian welding technology and research. Although an increasing number of papers from Russian welding journals, such as *Svarochnoe Proizvodstro*, *Avtomaticheskaya Svarka* and *Avtogennoe Delo* (now discontinued) have come to our attention in the form of abstracts and occasional translations, no direct information has been available about the extent and organization of welding research in the Soviet Union.

In November 1955, a group of welding engineers from Eastern Germany had an opportunity to visit many of the more important institutes and laboratories dedicated to welding research. Their report* makes very interesting reading and provides a good insight into the organizational setup and the scope of Russian research in welding and related fields.

Research Institutes

The institutes and laboratories active in welding research may be divided into three groups:

I. Institutes associated with the Academies of Science and technical colleges.
II. Institutes operated by the different industrial ministries.
III. Research laboratories maintained by large industrial plants.

Their assignments differ, but complement each other.

I. Academy Institutes

In these institutes, the emphasis is on basic research, but some of their developments have been of direct benefit to industry.

The most important institutions of the Academies of Science are:

1. The Institute of Metals of the Academy of Sciences of the USSR, at Moscow ("IMET") which has a welding research laboratory under the direction of Professor Rykalin. Its main interests are weldability of newly developed steels and process technology.

2. The "Paton" Institute of Arc Welding of the Ukrainian Academy of Science at Kiev. Its director is Professor B. Paton, son of the late founder E. O. Paton, and its range of activities covers all aspects of automatic welding including equipment development, welding design and technology. It is the center of automatic welding in Russia.

3. The Laboratory for Arc Welding Machines of the Academy of Science of the USSR, at Moscow, under Professor Nikitin. It is devoted to the development of arc-welding machines.

Eleven polytechnical institutes maintain departments of welding engineering with courses leading to a degree in welding engineering. Considerable research is also being done. Some of the more important ones are:

1. The "Bauman" Institute of the Moscow Polytechnical Institute, whose welding department is headed by Professor Nikolayev, pursues research in strength of materials, design, weldability and welding technology.

2. The "Kalinin" Institute of the Leningrad Polytechnical Institute has two chairs in welding engineering under Professors Okerblom and Alexeyev. Their research interest covers weld shrinkage, internal stresses, design, fatigue strength, welding machines.

3. The Kiev Polytechnical Institute has a welding engineering department under Prof. Khrenov which also does research work.

4. Moscow University has a department of steel construction under Professor Strelecki where welding problems connected with reinforced concrete and design are investigated.

II. Institutes of the Industrial Ministries

Each of the respective industrial ministries maintains at least one institute with a welding department. There are about 20 such departments and special laboratories. They are mainly concerned with applied research, but some fundamental problems are also within their scope of interest. Institutes of this type mentioned in the German report are:

1. The welding section of the Ministry for Heavy Machine Construction (TsNIITMASh) at Moscow, under the direction of Professor Lyubavskii, conducts research in welding electrodes, resistance welding, alloy steel, automatic welding processes and equipment. There is also a section for testing structural members under Professor Kudravtsev where internal stresses, fatigue strength, and welding design are studied.

2. The welding department of the so-called Nafta-Institute attached to the Ministry for the Petroleum Industry (VNIISGROINEFT) at Moscow is headed by A. S. Falkevich. It does research on pipeline and storage tank welding.

3. The welding department of the Railroad Bridge Institute of the Ministry for Transportation Construction (TsNII-MPS) at Moscow, under Dushinskii, deals with testing of structures and fatigue strength of welded joints.

4. The Ministry for Chemistry maintains a welding department (VNII-Avtogen) at Moscow. It is headed by Sheskov. Its research program includes all problems related to gas welding and cutting, equipment development, gas-shielded arc welding, metal spraying, flame scarfing.

5. The welding section of the Ministry for Communications at Moscow, under Professor Obukhov, is entrusted with the problems of copper welding, cast iron welding, gas pressure welding, and does also electrode testing.

III. Industrial Research Laboratories

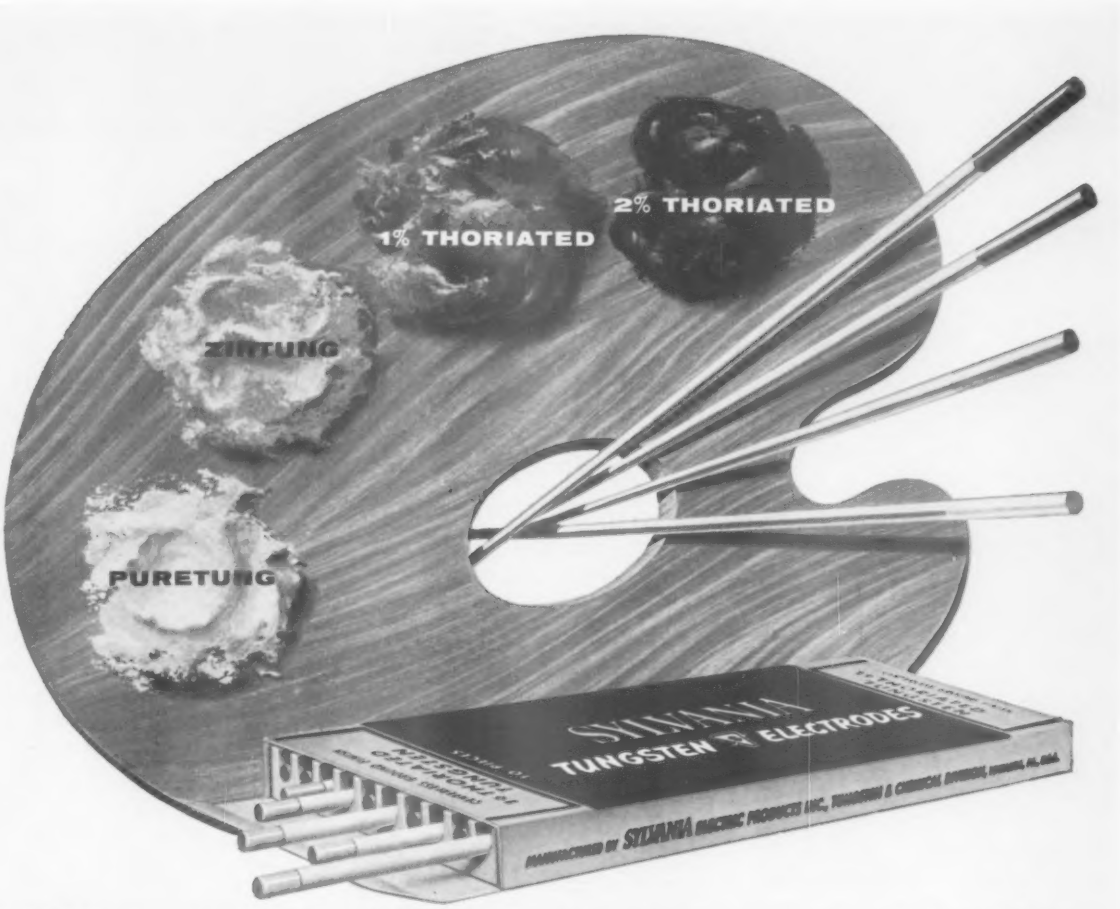
Some of the large plants engaged in heavy machine construction, fabrication of boilers and pressure vessels, steel construction, shipbuilding, etc., have exceedingly well-equipped research laboratories of their own. The German delegation visited the following industrial laboratories: (1) Podolskii (pressure vessels); (2) Taganrog (pressure vessels); (3) Stalin Works at Leningrad (turbines); (4) Kiev (shipbuilding); and (5) "Elektrik" Works at Leningrad (welding machines).

The research done in their laboratories is, of course, closely connected with the problems of the particular industry which they serve.

(*To be continued in April 1957 issue*)

Rudolph O. Seitz is affiliated with the Air Reduction Laboratories, Murray Hill, N. J., as information specialist.

* Neumann, A., "Die Forschung der Schweisstechnik in der Sowjetunion," *Schweisstechnik*, 6 (7), 194–199 (1956).



NOW—color coded for your convenience!

SYLVANIA TUNGSTEN ELECTRODES

Now all Sylvania Tungsten Electrodes are color coded . . . for greater safety . . . greater economy and convenience. You can tell the type of rod merely by glancing at the exposed end.

Used lengths of rods, regardless of size, no longer need to be scrapped for lack of identification. And no longer do you risk ruining a costly job because of choosing the wrong electrode. When you use Sylvania color coded electrodes, you know for certain which rod type you have in your clamp.

Color coding is just one of the many advantages that make Sylvania Tungsten Electrodes your best buy. Only Sylvania has the *complete* line—four types of electrodes, each designed for a specific job in shielded arc welding. Whether you use argon, helium, or atomic hydrogen, the four dependable electrodes will effectively meet almost any condition you may encounter.

Supplied with chemically cleaned or centerless ground finish, Sylvania Tungsten Electrodes are available in handy packages of ten color coded rods. For further information see your welding supplies distributor or write to:

SYLVANIA ELECTRIC PRODUCTS INC.
Tungsten and Chemical Division, Towanda, Pa.

TUNGSTEN • MOLYBDENUM • CHEMICALS • PHOSPHORS • SEMICONDUCTORS

SYLVANIA

Lighting • Radio • Electronics • Television • Atomic Energy

PERSONNEL

Past-President Hill Retires

H. O. Hill, a past president of the AMERICAN WELDING SOCIETY, has retired from the Bethlehem Steel Co. effective January 1st, concluding a career spanning nearly half a century.

Assistant chief engineer of the Fabricated Steel Construction Division, Mr. Hill's affiliation with Bethlehem began when the latter acquired McClintic-Marshall Co., of Pittsburgh, where he had been an engineer.

H. O. Hill

He began his industrial career with Riter-Conley Co., of Leetsdale, Pa., in 1908 as an estimator and designer. He remained there until McClintic-Marshall acquired Riter-Conley in 1916.

Mr. Hill was born in Stouffville, Ontario, Canada, and attended the University of Toronto from where he was graduated with a Bachelor of Science degree in Mechanical Engineering.

In addition to holding the AMERICAN WELDING SOCIETY presidency, Mr. Hill served on a number of important AWS committees including Committee on Rules for Field Welding of Storage Tanks, Committee on Standard Qualifications Procedure and the Technical Activities Committee.

He also served as chairman of the joint American Petroleum Institute–AMERICAN WELDING SOCIETY Conference Committee on Welding of Storage Tanks, was a member of the American Water Works Assn.—AMERICAN WELDING SOCIETY Committee on Specifications for Field Welding of Steel Water Pipe Joints and served on the American Water Works Assn.—AMERICAN WELDING SOCIETY Conference Committee on Elevated Steel Water Tanks, Standpipes and Reservoirs.

Other technical associations to which Mr. Hill has belonged are: American Society of Civil Engineers, American Society for Testing Materials, American Petroleum Institute, American Society of Mechanical Engineers, American Institute of Electrical Engineers and American Water Works Assn. He also is a Registered Professional Engineer of the Commonwealth of Pennsylvania.

Haley Appointed by Artco

The appointment of Thomas A. Haley as chief sales engineer of Artco's Engineering Division was announced recently by Herman E. Pravel, chief engineer of Artco, Inc., Fraser, Mich.

Thomas A. Haley

Mr. Haley is a graduate of Niagara University and was formerly a consulting engineer with the International Division of the Ford Motor Co. He will serve in an administrative, advertising and sales capacity for the four divisions of Artco.

Both Messrs. Haley and Pravel are members of the Detroit Section of the AMERICAN WELDING SOCIETY.

Flumerfelt Appointed to New Post

Metal & Thermit Corp., New York, N. Y., announces the appointment of Glen C. Flumerfelt to the post of Pacific Regional Manager, Welding Division.

Mr. Flumerfelt has been with M&T since early 1955 as a sales engineer. Prior to that he was regional manager on the West Coast for All-State Welding Alloys Co. He learned welding in various shops and shipyards in the San Francisco–Oakland area beginning

Glen C. Flumerfelt

in 1937, and is a member of the AMERICAN WELDING SOCIETY.

He will make his headquarters at the company's branch in South San Francisco and will, in addition, supervise the welding sales and warehousing activities of its Seattle, Wash., branch and its West Coast sales headquarters at El Segundo, Calif.

Fetherston Elected by School Boards Association

Thomas C. Fetherston, assistant director of public relations for Union Carbide and Carbon Corp., New York, was recently elected president of the New York State School Boards Assn., Inc., during its annual meeting in Syracuse, N. Y.

Mr. Fetherston is president of the Board of Education of Oceanside, N. Y., and has also held several executive positions with the New York State School Board Assn., prior to his election as president.

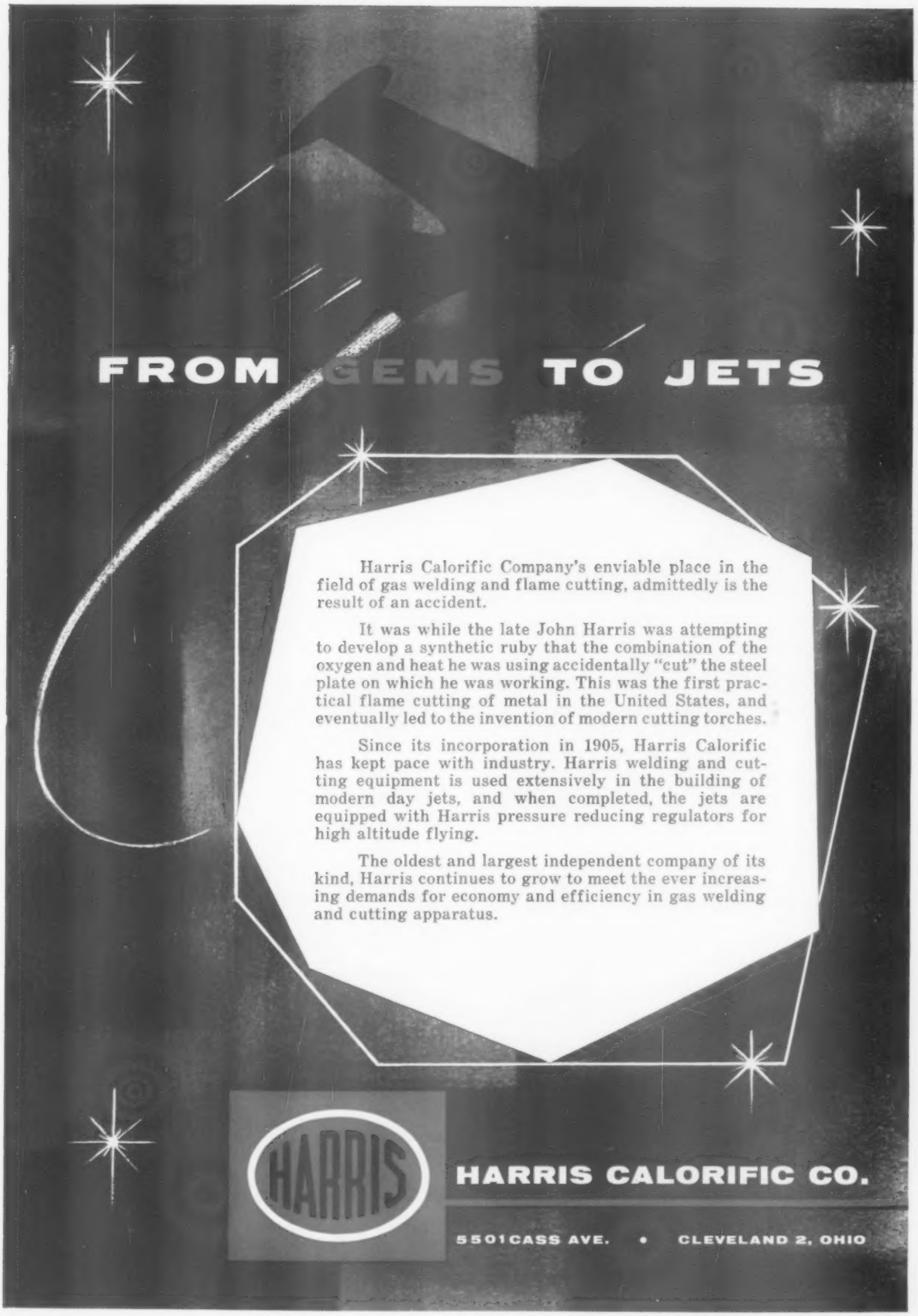
Mr. Fetherston is an active member of the AMERICAN WELDING SOCIETY.

Erich Named Sales Manager

Tube Turns Plastics, Inc., has announced the appointment of Earl Erich as sales manager of the company.

Mr. Erich was born in Allentown, Pa., and acquired his B.S. degree in chemistry at Muhlenberg College. He began his business career as a research chemist for the Atlas Mineral Products Co. Later he organized the company's Thermoplastics Division.

Mr. Erich joined the technical service staff of Tube Turns Plastics, Inc., on Jan. 1, 1955. In May 1955 he was


FROM GEMS TO JETS
Harris Calorific Company's enviable place in the field of gas welding and flame cutting, admittedly is the result of an accident.
It was while the late John Harris was attempting to develop a synthetic ruby that the combination of the oxygen and heat he was using accidentally "cut" the steel plate on which he was working. This was the first practical flame cutting of metal in the United States, and eventually led to the invention of modern cutting torches.
Since its incorporation in 1905, Harris Calorific has kept pace with industry. Harris welding and cutting equipment is used extensively in the building of modern day jets, and when completed, the jets are equipped with Harris pressure reducing regulators for high altitude flying.
The oldest and largest independent company of its kind, Harris continues to grow to meet the ever increasing demands for economy and efficiency in gas welding and cutting apparatus.
HARRIS
HARRIS CALORIFIC CO.
5501 CASS AVE. • CLEVELAND 2, OHIO

placed in charge of sales programs on the West Coast and in the Southwest. He was made assistant sales manager on Jan. 1, 1956.

He is a member of the AMERICAN WELDING SOCIETY, National Association of Corrosion Engineers, Society of the Plastics Industry and the American Chemical Society.

Schiebel Elected 2nd Vice-President

Roy O. Schiebel has been elected to the position of 2nd vice-president of the Magnaflux Corp. The election fills the newly created position of 2nd vice-president, sales and marketing.

Mr. Schiebel brings seventeen years of sales and management experience gained

Roy O. Schiebel

with the Magnaflux Corp. to this new position.

After two years as a field engineer in the home office, Mr. Schiebel was made Los Angeles Branch manager in 1942. After the War, in 1945, he came back to Chicago as Midwest District manager, and in 1952 Magnaflux Corp. asked him to move again— to New York as Eastern District and Export manager. Mr. Schiebel returned to Chicago as the sales manager in 1955.

Mr. Schiebel is particularly active as a member of the AMERICAN WELDING SOCIETY and the Society for Nondestructive Testing.

Lanier and Guest Promoted by Ingalls

Promotions of Monro B. Lanier to vice-chairman of the Board of Directors and W. R. Guest, Sr., to president of the Ingalls Shipbuilding Corp. have been announced by R. I. Ingalls, Jr., re-elected chairman of the Board, Ingalls Shipbuilding Corp., Pascagoula, Miss.

Mr. Lanier and Mr. Guest went to Pascagoula shortly before World War II to select a site and start operations of the Ingalls Shipbuilding Corp.

When the shipyard was incorporated Mr. Lanier was elected president, and Mr. Guest, executive vice-president. Both held these titles until the recent promotions.

Under the guidance and leadership of both Mr. Lanier and Mr. Guest a new concept in shipbuilding was successfully put into operation here in the yard, and at Ingalls former Chickasaw, Ala., plant. From this streamlined method of shipbuilding came the first all-welded ship, the tanker Transoil, constructed in 1934.

Since starting the shipyard in the '30's, Mr. Lanier and Mr. Guest have seen over 180 vessels completed and put into service throughout the world.

Mr. Guest went to Ingalls in 1916 as an engineer for the Ingalls Iron Works Co. in Birmingham. Three years later, in 1919, he was transferred to the sales department.

His next promotion was that of vice-president and sales manager, and in 1930 he became vice-president in charge of operation in Birmingham. Under his supervision, plants were established for the company in Pittsburgh and Decatur.

Both Mr. Lanier and Mr. Guest are members of the AMERICAN WELDING SOCIETY. Mr. Lanier is a former Director of AWS.

Richardson Made Assistant Sales Manager

Leon D. Richardson has been appointed assistant general sales manager of Eutectic Welding Alloys Corp., Flushing, N. Y. Prior to his appointment, Mr. Richardson had been Eutectic's sales manager for the Eastern States. In all he had been connected

Leon D. Richardson

with Eutectic for the last eleven years starting as a welding technician.

In pursuit of his increased responsibilities, he will work with Fred F. Rochll, vice-president and national sales manager, in directing the activities of

assures maximum use . . .
at minimum costs!
SS HI-C
TRACTOR GROUSER BARS
High Carbon Steel
for
REBUILDING WORN TRACTOR GROUSERS
• Attached quickly with any good grade of low hydrogen electrode.
• Easy to use with any manual or automatic electric welding method.
Write for BROCHURE SS HI-C and Price List
STULZ-SICKLES CO.
STEEL PRODUCERS 929-39 PORT AVE. • ELIZABETH, N. J.
NEAREST DISTRIBUTOR UPON REQUEST

Coke pusher shoes hardfaced with HF-20 alloy

600% INCREASED SERVICE LIFE

for coke pusher shoes hardfaced with AMSCO® HF-20

At Geneva Works of Columbia-Geneva Steel Division of U. S. Steel Corp., near Salt Lake City, obtaining economical performance from coke pusher shoes had been a problem. The shoes had to be hardfaced or replaced after only three months of use. This meant high maintenance costs and excessive downtime for their coke oven operation.

Their local Amsco distributor, Vern Taylor, suggested that a test be made, using 50 pounds of Amsco HF-20 hardfacing material, or approximately enough to hardface one shoe. The company agreed to his suggestion in an effort to solve their severe wear problem of heat and abrasion.

The coke pusher shoes are steel plate 3¾″ wide and 30″ long. HF-20 hardfacing, to a depth of ¼″ over the shoe surface, was applied for the test.

Test results proved to be more than satisfactory, for Amsco hardfacing *increased service life of the pusher shoes by 600%* . . . or from 3 months to 18 months. Today, hardfacing of coke pusher shoes with Amsco HF-20 is standard procedure at Columbia-Geneva Steel.

This is only one example of the ability of Amsco Hardfacing Materials . . . and Amsco Welding Distributors . . . to help solve wear problems where severe heat, abrasion, corrosion or impact are major factors.

Contact your Amsco Welding Distributor today for information on the full line of Amsco Hardfacing Electrodes and Welding Machines. Or write to American Manganese Steel Division, Welding Products Dept., Chicago Heights, Ill.

Amsco Welding Products distributed in Canada by Canadian Liquid Air Co., Ltd.

AMERICAN Brake Shoe COMPANY

AMSCO

American Manganese Steel Division • Chicago Heights, Ill.

OTHER PLANTS IN: DENVER, LOS ANGELES, NEW CASTLE, DEL., OAKLAND, CAL., ST. LOUIS, JOLIETTE, QUEBEC

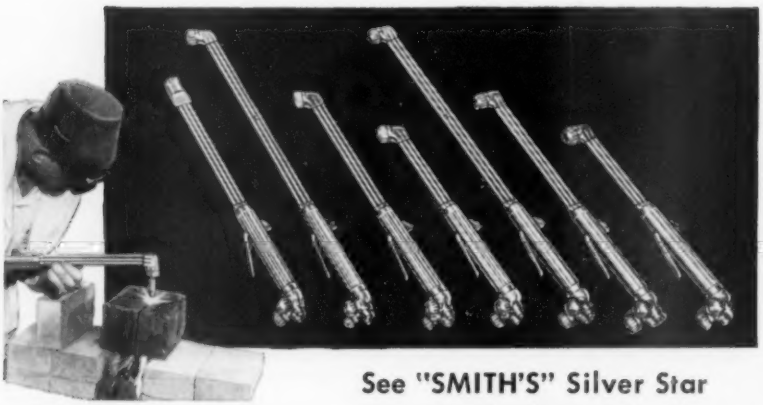
Looking Ahead?

. . . to the big 5th A.W.S. Welding Show?

Philadelphia, Pa., Convention Hall
April 9-10-11, 1957

We'll be there in Booth 113

And we'll have some interesting new equipment and demonstrations to show you
Stop in and see us! (Booth 113)



See "SMITH'S" Silver Star
—a star performer in the field of Oxy-Acetylene Cutting Torches

★ **Tests show average gas saving of 25¢ per hour**
★ **Reduces tip replacement cost as much as 50%**

SMITH WELDING EQUIPMENT CORP.
DEPT. WJ201 • 2633 S.E. 4th Street • Minneapolis, Minn.

Eutectic's more than 350 district engineers and field supervisors.

Mr. Richardson has had more than 20 years' industrial experience, most of it directly involving welding engineering and metallurgy. He is a member of the AMERICAN WELDING SOCIETY, Canadian Welding Society, American Society for Metals and the New York Sales Executives Club.

Kibby Joins Link Welder

William J. Kibby has recently become associated with Ernie Lauter, District Representative for the Link Welder Corp. of Detroit, Mich.

William J. Kibby

Cleveland offices are maintained at 2000 Center St., Cleveland 13, Ohio.

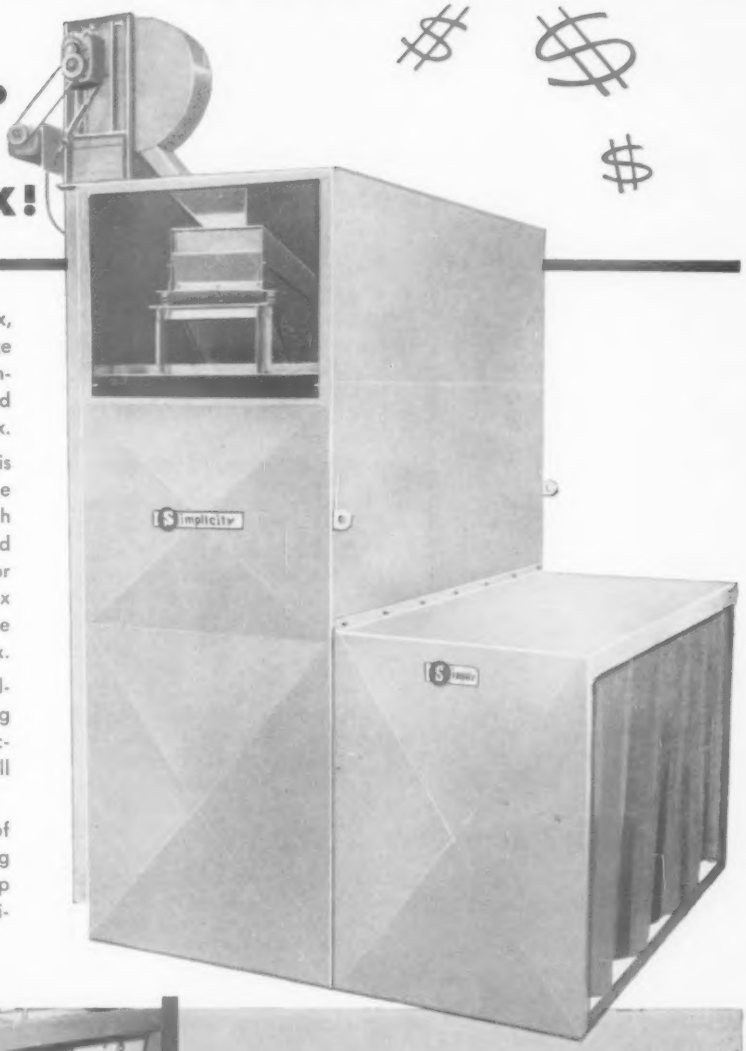
Mr. Kibby has been connected with the resistance welding field for the last ten years. He is a member of the AMERICAN WELDING SOCIETY.

HAWKINS PROMOTED BY AIRCO

George E. Hawkins, vice-president of Air Reduction Co., Inc., has been elected executive vice-president of the company by the board of directors. Mr. Hawkins joined the company in 1917, has been vice-president since 1941, and a director since 1949

THROWING MONEY AWAY?

YOU ARE, IF YOU SCRAP SPILLED AND FUSED FLUX!

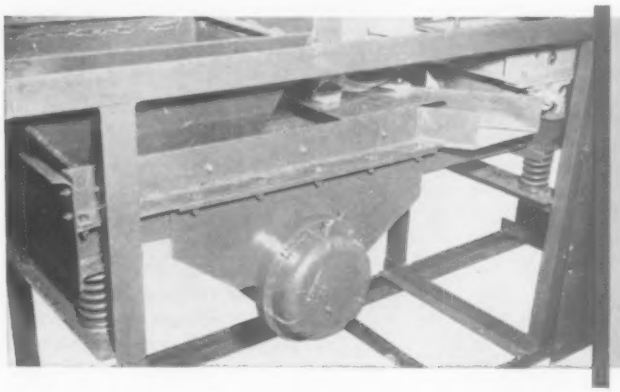


When you discard spilled and fused flux, you're throwing profits to the wind. A large automotive plant solved this problem by installing the Simplicity Flux Reclaim Unit, and saving $5,000 a month salvaging used flux.

Sound good? It should, if your plant is equipped with submerged arc welders. The Simplicity Flux Reclaimer is designed to crush used flux, remove metal particles, dust and fines, and give you refined flux ready for re-use. Mixed in proper ratio with new flux (depending upon type of work) welds are obtained equal to those made with new flux.

Equipped with a two surface vibrating feeder, bucket elevator, double deck vibrating screen, 15" x 9" crusher and two magnetic-pulleys, the Simplicity Flux Reclaimer will more than pay its own way.

Complete installation drawings and prices of these SIMPLICITY units may be had by writing directly to the factory . . . a logical first step in determining ALL the money-saving possibilities these machines may hold for you.



View of 12" x 4'9" two surface oscillating feeder, showing side discharge for removing scrap, metal particles and other foreign objects.

195

SALES REPRESENTATIVES IN ALL PARTS OF THE U.S.A.
FOR CANADA: Simplicity Materials Handling Limited, Guelph, Ontario.
FOR EXPORT: Brown and Sites, 50 Church Street, New York 7, N. Y.

Simplicity
TRADE MARK REGISTERED

ENGINEERING COMPANY • DURAND 23, MICHIGAN

NEW PRODUCTS

Gas-Shielded Arc-Welding Unit

A new semiautomatic welding unit, which provides versatility and economy in CO_2 and inert-gas metal-arc welding, has just been announced by Hobart Bros. Co., Troy, Ohio.

The unit is designed for use with Hobart "Powromatic" constant voltage type welder, but will operate with any

constant voltage type d-c power source. It consists of a welding control and electrode drive unit, and interconnecting gas, water and cable assemblies.

The function of the unit in consumable electrode welding is to feed the electrode into the arc at a constant, preselected speed. It provides a means for starting and stopping the arc, adjusting the electrode feed speed, "inching" the electrode, controlling the arc welder power and controlling the flow of shielding gas—automatically and in proper sequence.

Complete information on this new unit is available from Hobart Brothers Co., Troy, Ohio.

Aluminum Soldering Sheet

A new product, which reportedly promises to eliminate many of the problems associated with smooth and economical soldering of heat-exchanger equipment, has been announced by Aluminum Company of America. Zinc-clad aluminum alloy, long in the research and development stage, is now available for the first time in commercial quantities.

Fabricated with one or both sides clad, and in coil or flat sheet form, the product, designated Alcoa soldering sheet, is described by manufacturer as bringing aluminum within range of the ease of solderability heretofore enjoyed by copper.

Used with specially developed Alcoa soldering techniques, zinc-clad aluminum is expected to simplify normal maintenance and repair problems of soldered assemblies, in addition to reducing costs of production methods.

For complete details write to Aluminum Company of America, 1501 Alcoa Bldg., Pittsburgh, 19, Pa.

Arc-Welding Machines

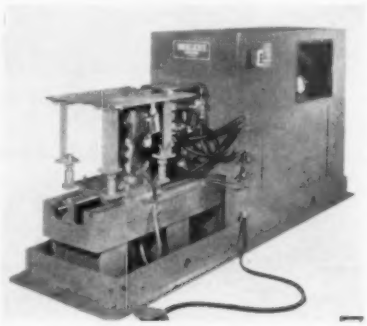
A new arc-welding machine and accessory catalog is now available from Air Reduction Sales Co.

Selenium rectifier and d-c motor generator arc welders for industrial welding, a-c and d-c engine-driven arc welders for construction and maintenance, a-c transformer arc welders for construction and maintenance, a-c transformer arc welders for plant, farm, ranch, garage and shop use are examples of the complete Airco line of welding machines illustrated and described in this catalog. Specifications for each machine, from ampere ratings to outside dimensions, are included.

A copy can be obtained by writing Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y. Specify form ADC 708C.

Horizontal Seam Welder

Sciaky Bros., Inc., 4915 W. 67th St., Chicago, Ill., announce the new design of an air-operated, single-phase MX-400 horizontal seam welding machine. This new resistance welding machine is being used in high production work by a nationally known manufacturer of combustion heating equipment to fabricate furnace bonnets.



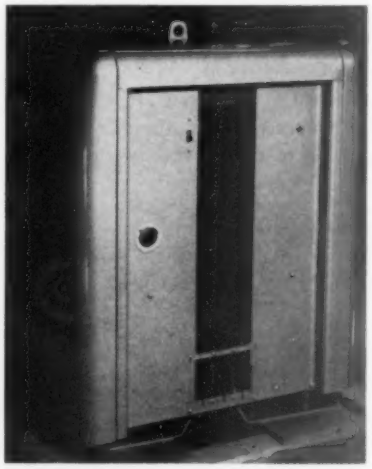
The machine's pressure system is capable of applying a maximum electrode force of 3000 lb under an air line pressure of 80 psi. The upper and lower electrode heads are supplied with silver contacts. The upper electrode wheel (to the right) is driven by means of an internal gear drive. The lower wheel (to the left) is the idler and is inclined to clear the piece-part design.

For more information regarding this horizontal seam welder, write to Department M-14 at the Chicago address.

1000-Amp Welder

A new 1000-amp, a-c transformer welder, designed primarily as a power source for the submerged-arc process, has been announced by the General Electric Co.'s Welding Department.

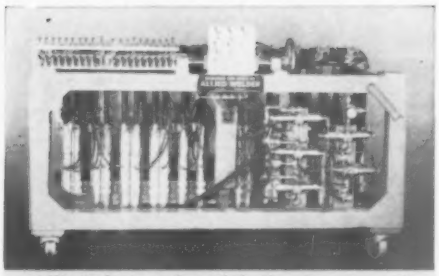
With an operating range of 325 to 1000 amp, the new single-phase welder has motor-driven current control. By means of a plug and receptacle, remote



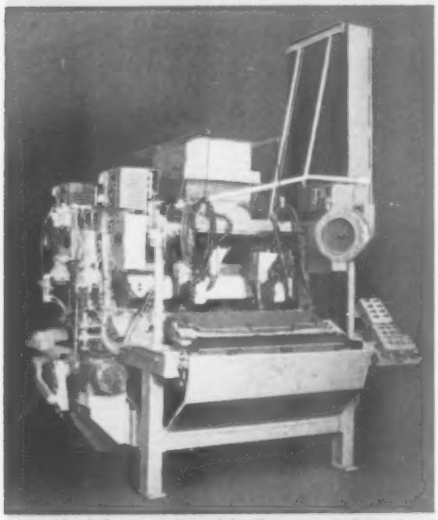
control of both welder output and primary contactor is available, in addition to the controls mounted permanently on the welder case.

With output open-circuit voltages of 85 to 100 v, the unit has power factor correction capacitors and operates on a reconnectable 230/460-v input. Built into the welder is a 2-kva control transformer, which can be used externally for operating of auxiliary equipment.

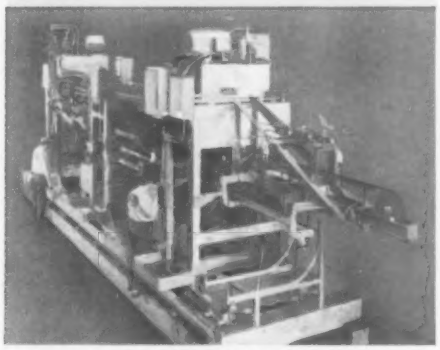
For complete details, write directly to General Electric Co., Welding Department, Schenectady 5, N. Y.



Allied designed and built air operated machine for drilling 20 holes simultaneously in trailer floor.



Allied designed and built automatic over and under arc welder. Welds automotive frame X member.



Allied designed and built automatic two-stage resistance welder with transfer and turn over devices. Welds radiator support assembly.

how big is your problem . . .

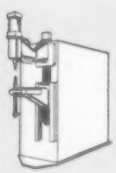
Really?

If it involves special equipment for a production welding operation it may not be a problem at all— just an assignment when placed in competent hands.

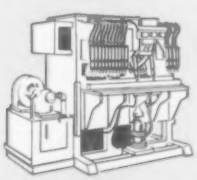
This is our kind of work – we specialize in it – do it every day; designing and building special machines for welding everything from bathtubs to trailers, frequently including provisions for automatic handling and transfer where the job is a part of a production line set-up.

We're no brain trust here at Allied Welder, but we keep some awfully important production people happy with our creative designing and manufacturing know-how, delivery, too.

May we work with you on your next job?

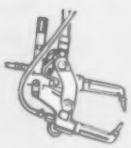


Standard Welders



Special Welders

Automation Equipment



Automatic Arc Welders

Welding Guns

ALLIED WELDER CORPORATION

8700 BRANDT DEARBORN, MICHIGAN

Creative Design

Iron-Powder Build-up Electrode

A new iron-powder build-up electrode has recently been developed by the McKay Co., Pittsburgh.

Known as Hardalloy "32", the new iron-powder low-hydrogen electrode is said to deposit a surface that resists extreme impact and moderate abrasion. The electrodes operate well with either a-c or d-c welding equipment and have a deposition rate 25% faster than conventional types.

A descriptive bulletin, giving full specifications, composition and application data, is available from the McKay Co., 1005 Liberty Ave., Pittsburgh, 22, Pa.

Cable Connector

Jackson Products, Warren, Mich., announce the availability of their improved "Quik-Trik" Cable Connector. These neoprene rubber insulators, strongly built around steel sleeves, have tapered ends to stretch over the welding cable snugly. They are said to lock out moisture, oil and dirt, and do not catch against obstructions. Also, they will not break and scatter, leaving the electrical connection exposed.

According to manufacturer, no capital equipment is needed for installation, nor time-consuming vulcanizing. Simply loosen an Allen screw, slide off the insulator and slip it over the cable end. Then, connect cable as usual, slide back the insulator and tighten.

Model 2/0-R takes cables 1/0 and 2/0, with mechanical, soldered or brazed connections. Model 4/0-R takes cables 3/0 and 4/0, soldered or brazed connections only.

For more complete details, see ad on inside front cover of this issue; also, write directly to Jackson Products at above address.

Induction Heating Unit

A new 400-cycle induction type heating unit manufactured by Hobart Bros. Co., Troy, Ohio, reportedly permits preheating and stress relieving to be carried out economically in one continuous cycle without necessity of moving the weldment for furnace treatment or other operation.

When the preheat temperature has been selected, the controlling instrument heats to this temperature and holds it accurately until welding begins. After the weld is completed, the instrument automatically starts the desired stress relieving program. During this time, only enough heat is added to meet specifications exactly.

For more complete information, write to Hobart Bros. Co., Troy, Ohio.

Iron-Powder Electrodes for Hard Surfacing

Alloy Rods Co., York, Pa., announces that it has developed a new line of iron-powder coated hard-surfacing alloys.

The new iron-powder hard-surfacing electrodes are manufactured in three types; Wear-Arc 3 I.P. for build-up of worn parts: Wear-Arc 6 I.P.—an all-position electrode with excellent resistance to abrasion, impact and compression: and Wear-Arc 12 I. P.—where extreme resistance to wear caused by heavy impact and abrasion is required.

According to manufacturer, tests with the new iron-powder hard-surfacing electrodes have proved that an average welder can deposit 1 lb of weld metal in three fourths the time it previously

Man,
this ZIP electrode's
the greatest!

He's right. The new Westinghouse ZIP-14 universal electrode handles easily in all positions, has very low spatter loss, deep penetration, fast burnoff, feather-touch slag removal and a quiet, smooth arc. This powdered-iron electrode fits both E-6014 and E-7014 classifications. There's no burning through, no undercutting even on vertical down work.

What more can you ask for in an electrode?

We know you'll like it. Try it in your own shop—under your conditions! It will sell itself! J-21984

Only Westinghouse offers this welding leadership!

YOU CAN BE SURE...IF IT'S Westinghouse

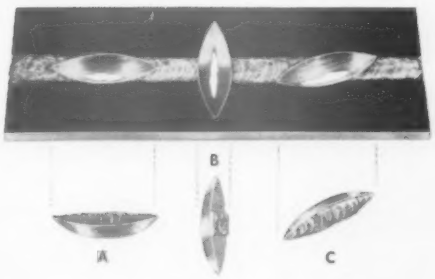
Portable (by one man) for easy quick clean sampling

FIBRE-METAL'S

WELD-PROBER

CUTS SPECIMENS FROM BUTT WELDS FOR

visual inspection



Longitudinal, transverse and oblique (a, b & c) specimens removed by Weld-Prober. Below are drawings of tension and bend test (d & e) specimens that may be machined from them.

The Weld-Prober cuts out specimens from butt welded joints so that the quality and soundness of the weld may be examined. Such specimens reveal the workmanship of the weld by exposing defects, if any, such as slag inclusions, lack of fusion, cracks or porosities. Physical and mechanical properties of the joint can also be determined by machining the specimens into tensile, bending, impact or other form of test piece.

Of particular advantage is the favorable shape of the cavity produced by the Weld-Prober. This opening can be quickly and easily re-welded without further preparation and without a backing plate.

The Weld-Prober is basically a spherical saw driven by an electric motor through reduction gearing. Mounting is such that opposing positioning produces the specimen shown . . . up to 1⅛" deep.

The Weld-Prober will operate equally well on flat, vertical, horizontal or overhead joints . . . or on irregular and cylindrical surfaces such as pipes and on concave surfaces as the insides of vessels.

USED BY

U. S. Navy yards, Shipbuilders, Tank manufacturers, Boiler makers, Public Utilities, Refineries, Auto and Farm Machinery producers, Pipe Line contractors, Structural Steel fabricators.

ADVANTAGES OF WELD-PROBER TEST

1. Positive check on welder's workmanship.
2. Mechanical and physical properties of welded joint ascertained from completed work.
3. Removal of solid specimen containing full portion of welded joint.
4. Specimen large enough to be machined into test pieces for laboratory tests.
5. OPENING EASILY RE-WELDED.
6. Strength of joint not decreased.
7. Appearance of seam not impaired.
8. Test can be made in any position and on irregular surfaces.
9. Weld-Prober is portable and can be handled by one man.
10. Weld-Prober is easily operated and does not require expert handling.
11. Test is practical and economical.
12. Does not interfere with or hold up production.

Write for our descriptive booklet, "THE WELD-PROBER"

THE WORLD'S LARGEST MANUFACTURER OF SUPERIOR WELDING EQUIPMENT

Sold Everywhere thru Leading Distributors and Dealers

The FIBRE-METAL Products Company | CHESTER PENNA.

WELDING HELMETS • SPEEDY ATTACHMENTS • SUPERGARD HATS & CAPS • INSULATED EUREKA HOLDER • FACE SHIELDS • WELD CLEANING HAMMERS • FRESHAIR SYSTEMS

Visit us at The WESTERN METAL CONGRESS & EXPOSITION, Los Angeles, March 25-29: Booth 1243

took him with conventional build-up and hard-surfacing electrodes.

Complete information and descriptive literature are available from the manufacturer, Alloy Rods Co., 3505 Lincoln Highway West, York, Pa.

Aluminum Forge-Welding Process

A new proprietary process for welding the high-strength aluminum alloys such as 7075-T6, 2024-T4 and 2014-T6, now reportedly makes it possible to produce 95 to 100% joint efficiency in the as-welded condition. The best combination of high weld strength and ductility ever obtained in an aluminum alloy was recently reported from welds in 7075–T6, $^3/_4$ in. diam bar. The results as-welded: 78,800 psi ultimate tensile strength; 6% elongation (several samples broke away from the weld outside the gage marks); 102% efficiency.

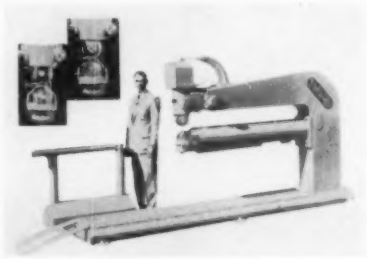
The Alforge process, developed by engineers of Ravens-Metal Products, Ravenswood, W. Va., is described as being a carefully controlled type of forge welding in which die design, clean surfaces, temperature-pressure relationships and amount of metal upset are the main variables to be controlled. The time-temperature relationship must be such that ductility and good flow characteristics result without overaging the base metal.

Photomicrographs of the weld show no evidence of the original interface; however, flow lines and evidence of cold work are apparent (see accompanying photo). The fracture surfaces of tensile specimens are clean and resemble similar fractures in the base metal.

For complete details, write directly to the company at above address.

Weld Roll Planisher

A new weld roll planisher, featuring rotating heads, is announced by Airline Welding & Engineering Co., 785 N. Prairie Ave., Hawthorne, Calif. These rotating heads can be turned 90 deg and locked in position for planishing circumferential welds as well as longitudinal welds on tubes, tanks, cones and other shapes. Vise-type locks hold the upper and lower heads in position. This $6^1/_2$-ton planisher has a 72-in. throat. Pressures up to 10 tons and



up to 96-in. throat depth are available. The upper head is power driven by geared head motor and chain drive. There are no size limitations for large diameter tubes. For small diameters, a traveling backing attachment is supplied for small tube weld roll planishing.

Cold working and smoothening of fusion welds by roll planishing eliminates grinding and improves the mechanical properties of the weld and the heat-affected zones, the manufacturer points out.

Write to manufacturer for further information.

AT THE FRONTIERS OF PROGRESS YOU'LL FIND

FOR WELDING AND CUTTING...

IN THE RED DRUM

HIGHEST QUALITY

DUST-FREE

AN AIR REDUCTION PRODUCT

NATIONAL CARBIDE

Write for the name and address of the NATIONAL CARBIDE supplier nearest you.

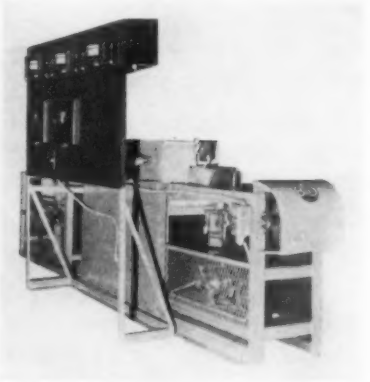
National Carbide Company

GENERAL OFFICES: 150 EAST 42ND STREET, NEW YORK 17, N.Y.

A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

Transistor Furnace

A new type electric furnace specifically designed for alloying, brazing and soldering of transistors and other semiconductor products has just been announced by BTU Engineering Co. of



Boston, Mass. Known as the BTU "Transheat" Furnace, it is said to be custom designed, engineered and built to yield the time-temperature curve that is best suited for any given application.

For free literature, write BTU Engineering Co., 440 Somerville Ave., Somerville 43, Mass.

NEW LITERATURE

Brazing News

Handy & Harman, 82 Fulton St., New York 38, N. Y., announces the availability of their latest bulletin on *Low Temperature Brazing News*. For your free copy of this four-page bulletin (No. 75), write directly to the company.

High-Temperature Alloy for Jet Engines

A new high-temperature nickel alloy which is expected to find wide use in highly stressed parts of jet engine combustion systems was announced recently by the International Nickel Co., Inc. It is also possible that the new material, which will be marketed under the trademark Incoloy "T," will find future application in airframe parts of planes to be used for hypersonic flight at speeds encountered in the region of the thermal barrier.

Incoloy "T" titanium-containing nickel-iron-chromium alloy is produced as a strong sheet material designed to operate at temperatures up to 1400° F and in some applications even higher. It is similar in composition to Incoloy nickel-iron-chromium alloy and contains in addition about one per cent titanium.

A basic data sheet on Incoloy "T" alloy can be obtained by writing to the Reader Service Section, International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Technical Digest Service

The Technical Digest Service, Inc., has inaugurated a new service to the metals industry—the publication of monthly digests and digest-translations of current articles on production, design, development and research from the journals of the world. That material which, in the judgment of an International Board of Editors, is of prime industrial importance, is translated, condensed and evaluated by practicing metallurgists and presented, factually complete and abundantly illustrated, in a format designed for quick and easy use.

Under the general editorship of Prof. E. S. Machlin (Columbia University), and with the aid of a distinguished Advisory Board of Editors, the Technical Digest Service offers subject series covering foundry, forging, sheet metal practice, wire and rod practice, powder metallurgy, welding, joining and metals refining.

Additional series, individually drafted to meet the special needs of subscribing companies, will be made available, as will consulting services.

For a descriptive brochure, write to the Technical Digest Service, Inc., 122 E. 55th St., New York 22, N. Y.

Welding Accessory Catalog

A new 16-page catalog EW-196 covering a complete line of welding acces-

sories and supplies is being mailed free of charge on request to Hobart Bros. Co., Troy, Ohio.

Stainless Steel Honeycombs

The Engineering Research Department of the American Silver Co., Flushing, N. Y., has prepared a comprehensive bibliography dealing with stainless steel honeycombs. It can be obtained free of charge from the Technical Editor, American Silver Co., 36-07 Prince St., Flushing 54, N. Y.

The bibliography gives the titles and publication references of articles published since 1950 on: fabrication, assembly welding, brazing, testing, designing, engineering and other aspects of stainless steel honeycomb technology. It also contains titles of company publications in this field, gives addresses and instructions for their procurement.

Iron-Powder Electrodes

The outstanding success of iron-powder electrodes in the welding industry, their performance factors and AWS specifications are fully covered in this new folder recently announced by Hoeganaes Sponge Iron Corp., Riverton, N. J.

Technical data are presented not alone on welding performance of iron-powder electrodes, but also on their iron powder, Ancor W-428, used as a coating of the rods.

Free copies are available by requesting Form No. 106 directly from the manufacturer at the above address.

BOUND VOLUMES OF 1956 JOURNAL NOW AVAILABLE

Bound Volumes of THE WELDING JOURNAL for the year 1956 are available in black imitation leather covers, together with a comprehensive subject and authors index. Price $15, including postage.

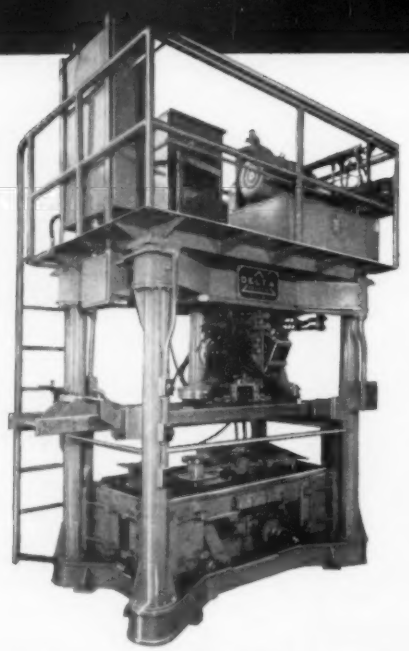
This volume, comprising a total of 1296 pages in the JOURNAL and an additional 624 pages in the *Welding Research Supplement*, represents a veritable encyclopedia of information in the welding field. Copies may be ordered through the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y.

HIGH PRODUCTION RESISTANCE WELDING

DELTA

WELDER CORP.

MACHINES AND EQUIPMENT



High production resistance welding equipment and automation devices . . . designed, engineered, and manufactured by Delta Welder . . . that's the "know-how" which assures lower production costs and improved product quality!

The record of outstanding performance compiled by Delta Welder equipment and automation devices is worth your examination.

Permit our sales engineers to show you Delta Welder equipment developments and machines that are saving time and money for nationally known manufacturers. Write or call. No obligation. Ph. Texas 4-8446.

DELTA WELDER CORPORATION

8525 Livernois • Detroit 4, Michigan

INDEX TO ADVERTISERS

Air Reduction . . . . . 283, 291, Outside back cover
Allied Welder Corporation 333
Alloy Rods Co. 313
All-State Welding Alloys Co., Inc. 320
Aluminum Company of America 288, 289
American Chain and Cable 300, 301
American Manganese Steel Div. 329
Arcos Corp. 296, 297
Aronson Machine Co. 298

Becker Bros. Carbon Co. 322

Cam-Lok Div., Empire Products Co. 317

Delta Welder Corporation 338
Drawalloy Corp. 309

Eastman Kodak 321
Eutectic Welding Alloys Corp. 307

The Fibre-Metal Products Company 335

General Electric 292, 293

Harris Calorific Co. 327
Hobart Bros. Co. 211

International Nickel Co., Inc. 265

Jackson Products, Inc. . . . . Inside front cover

Lenco, Inc. 318
Lincoln Electric Co. 311
Linde Air Products Company, a Division of Union Carbide and Carbon Corp. 214

P. R. Mallory & Co., Inc. 213
Metal & Thermit Corp. 323
Miller Electric Manufacturing Co., Inc. 218

National Carbide Company 336
National Welding Equipment Co. 212

Page Steel and Wire Division 300, 301

Sciaky Bros. Inc. 285
Severn Engineering Company, Inc. 322
Simplicity Engineering Co. 331
A. O. Smith Corporation 304, 305
Smith Welding Equipment Corp. 330
Stulz-Sickles Co. 328
Sylvania Electric Products, Inc. 325

The Taylor-Winfield Corporation 303
Tempil® Corp. 308
Thermacote Company 316
Tweco Products, Inc. . . . . Inside back cover

Union Carbide and Carbon Corporation
Linde Air Products Co. 214

Victor Equipment Company 295

Westinghouse Electric Corporation 315, 334

Welding Research

SPONSORED BY THE WELDING RESEARCH COUNCIL
OF THE ENGINEERING FOUNDATION

W. SPRARAGEN, DIRECTOR

SUPPLEMENT TO THE WELDING JOURNAL, MARCH, 1957

EFFECT OF IRRADIATION ON WELDABILITY OF ASTM A212, GRADE B

Tests indicate that prior irradiation by an integrated thermal flux of 10^{16} nvt does not have much effect upon the weldability of pressure-vessel material

BY WENDELL R. HUTCHINSON

SUMMARY. In an endeavor to ferret out difficulties that might be encountered during the rewelding of the Mark I and Mark II pressure vessels, weldability tests were conducted on ASTM A212, Grade B pressure plate material in both the irradiated and unirradiated conditions. An integrated thermal neutron flux in excess of that anticipated at the time of rewelding the Mark I pressure vessel was chosen for this investigation.

No difficulties were observed during the welding of the test plates nor were any harmful effects noted during subsequent testing to indicate an irradiation-weldability relationship. The only factor observed which might influence the quality of a weld made on irradiated A212 material was the encumbrance of the welder with additional clothing and safety procedures and the resultant psychological effects on the quality of his work.

Introduction

In view of the difficulties encountered during the attempted repair welding of the thermal shield for the N.R.X. Reactor, Chalk River, Ont., and the anticipated rewelding of the Mark I and Mark II pressure vessels, it was deemed advisable to investigate the weldability of irradiated pressure-vessel material.[1]

G. W. Hatfield, in his report,[2] suggests that the welding difficulties encountered may have been due to some peculiar transformation caused by intensive pile radiation. Undoubtedly welding outdoors by 15 welders[3] under hazardous radiation conditions in Canadian November weather added to the complexity of the problem.

Wendell R. Hutchinson is a Senior Engineer, Materials and Processes Section, C.T.A., Westinghouse Electric Corp., Bettis Plant, Pittsburgh, Pa.

To be presented at 1957 AWS Spring Meeting in Philadelphia, Pa., April 8th to 12th.

Irradiation Theory and Background

Fissioning of a U^{235} atom produces an average of 2.5 fast neutrons at an energy of approximately one million electron volts (1 Mev).[4] These neutrons are slowed down by the reactor-moderating material to thermal energies of the order of one-fortieth of an electron volt (0.025 ev) to sustain the chain reaction in the thermal reactor.[5] As a result, a spectrum of neutron energy levels is created. Neutrons with an energy level of one thousand electron volts (Kev) or over are classified as intermediate or resonance neutrons and those with an energy level less than one-tenth of an electron volt (0.1 ev) are classified as thermal neutrons.[6]

The degree of thermalization of the neutron flux in the thermal reactor may be determined from the cadmium ratio. Cadmium absorbs all thermal neutrons with energies under 0.5 ev while indium preferentially absorbs neutrons at its resonant energy level of 1.5 ev. Indium and cadmium covered indium foils are exposed to neutron flux and the resultant activity of both foils is determined. The ratio of the activity of the unshielded indium foil to that of the cadmium-shielded foil is called the cadmium ratio.[7]

In metal, irradiation damage is caused almost entirely by fast neutrons with energy levels up to 100 Kev.[8] At higher energy levels dissipation of energy is primarily by ionization.[9] Irradiation damage is believed to be due to vacancy-interstitial pairs, thermal spikes and impurity atoms.[10–12]

Vacancies result from the displacement of atoms from their equilibrium positions by bombardment. While these atoms are in motion, they are called *knock-on atoms*. Usually, they have sufficient energy to dislodge other atoms in turn. Upon coming to rest in non-equilibrium positions, they are then termed *interstitial atoms*.[10] The presence of these artificially created vacanies is also believed to increase diffusion rate.[13]

Thermal spikes are continuous paths of 5000 to 10,000 atoms heated to 1000 to 1500° K for 10^{-3} sec by a high-energy neutron.[10] The temperature of these thermal spikes may induce rapid annealing or phase changes in a material normally stable at ambient operating temperatures.[14]

Least important of these effects is that of *impurity atoms* which result from transmutations under neutron bombardment. Only one impurity atom is formed for every 2000 vacancies, interstitial atoms, and thermal spikes. Normal unfissionable materials should not be affected by this effect for 10 to 20

yr at an integrated fast flux of 10^{14} nv.*,[14]

Cold working is the usual analogy made to explain the effects of irradiation damage. One of the best analogies, however, is that of solution hardening where the presence of impurity atoms in the lattice has the same effect as radiation damage.[15]

The amount of energy required to displace an atom from its normal lattice position is approximately 25 ev,[16] whereas the energy required for recovery of mechanical properties from radiation damage is equal to that required for self-diffusion in the metal.[17] This value for an iron crystal has been found to be 3.1 ev.[18]

Experimental data indicate that the general effect of radiation on iron and ferrous alloys is to raise strength properties at a sacrifice of ductility and impact transition temperature. These effects are clearly illustrated in Fig. 6 of "Effects of Neutron Irradiation in Steel,"[19] in which A212 material was irradiated by an integrated fast flux of 10^{19} and 10^{20} nvt. It is of interest to note, however, that reduction of area was raised at the lower irradiation level. Similar indications were observed in iron crystals irradiated to 10^{18} nvt* in a thermal flux of 10^{12} nv.[20]

Raising the temperature of material increases the thermal energy of motion. As a result, this higher activity level increases the probability of an atom having sufficient energy to overcome radiation-induced lattice distortion.[21,22] One hour at 425° C was sufficient to restore the room temperature impact strength of A212 material subjected to 15 to 21 $\times$ 10^{19} nvt integrated fast flux while an hour at 300° C had no effect.[23]

As in other annealing and recovery processes, recovery from radiation damage has been found to be time as well as temperature dependent. Single iron crystals irradiated at Brookhaven National Laboratory to 2 $\times$ 10^{18} nvt showed an increase in yield strength of 5000 psi over the unirradiated 7000 psi yield strength. Subsequent heat treatment at 200 to 500° C for 1 to 10^4 min showed that recovery time increases approximately exponentially for each 25° C drop in annealing temperature. The approximate recovery times given in Table 1, followed the self-diffusion-type formula $\tau = Ae^{Q/KT}$,[20] where:

τ = recovery time for fixed extent of recovery,
T = absolute temperature,
A = proportionality constant,
Q = activity energy,
K = constant.

From Fig. 3 of Reference 24 it was possible to derive the formula $\log \tau = 15.2(10^3/T) - 26.4$ as shown in the Appendix. τ is time in min and T is temperature in degrees Kelvin. Approximate recovery times may be calculated at other temperatures if this relationship may be extrapolated beyond the experimental data. Calculated time at 225° C gave 1.6 $\times$ 10^4 min or approximately 10 days. This corresponds to 50% recovery in the above table. By similar calculation, the time required for 50% recovery at 175° C is 3.2 $\times$ 10^7 or approximately 55 yr. Thus, temperatures under 175° C for periods less than a week in duration should not appreciably reduce a given amount of radiation damage.

From consideration of the foregoing literature survey, it may be concluded that adverse irradiation effects on the mechanical properties of steel are due primarily to the displacement of atoms from their normal positions in the crystal lattice. Recovery then, as the reversible process of radiation damage, is dependent upon time and temperature for the return of interstitial atoms to their normal positions in the crystal lattice.

The rate of recovery of a steel in radiation service would be opposed by the neutron flux or rate of radiation damage. The degree of damage or saturation damage level of such a material would depend upon the equilibrium between the damage rate and the recovery rate. At elevated temperatures, the equilibrium would favor recovery; at low temperatures, it would favor radiation damage.

Initial recovery rate is influenced by the degree of radiation damage. The larger the number of atoms displaced by radiation, the larger will be the number of atoms having sufficient thermal energy to overcome the radiation-induced lattice distortion.

Since radiation-induced lattice distortion is unstable thermodynamically,[21] and a minimum of approximately 25 ev are required to displace an atom from its normal position, it is postulated that a neutron flux capable of imparting less than approximately 25 ev to an atom and more than that required for the self-diffusion activation energy level of 3.1 ev could improve ductility by reducing the number of interstitial atoms and vacancies in the crystal lattice.

Such reactions as transmutations, decompositions, and phase changes are probably irreversible under normal reactor operating conditions but may be encountered at integrated thermal fluxes in excess of 10^{20} nvt. To date, these reactions have not been encountered as serious radiation effects in reactor structural materials.[25]

Table 1—Approximate Recovery Time in Minutes

Anneal temp., ° C.	25% Recovery	50% Recovery	75% Recovery
225	1.2×10^3	1.5×10^4	
250	0.7×10^2	1.2×10^3	
275		1.0×10^2	1.4×10^3
300		0.4×10^1	1.0×10^2

Materials Used in the Investigation

The ASTM A212 Grade B pressure plate material was supplied in the normalized condition. The manufacturer's data on chemical analysis and

Table 2

Chemical analysis of A212 pressure plate material

Test	Heat No.	Slab No.	Plate size, in.	C	Mn	P	S	Si
Modified Navy "torture" test	22090	1	2	0.25	0.80	0.014	0.030	0.22
Circular-bead underbead-cracking test	23229	4	1 1/2	0.24	0.70	0.018	0.024	0.23
Tee-bend test	22099	9	1/2	0.19	0.75	0.024	0.030	0.19

Mechanical properties of A212 pressure plate material

Heat No.	Slab No.	Plate size, in.	Yield, psi	Tensile, psi	Elongation, %	Reduction of area, %
22090	1	2	..	76,000	..	..
			42,200	74,700	20.5	58.0
23220	4	1 1/2	..	73,100	..	..
			45,800	71,100	32.0	56.4
22099	9	1/2	..	71,600	..	..
			44,300	70,900	31.0	59.1

* Where n is neutrons per cm², v is velocity in cm per sec and t is time in sec, neutrons per cm²-sec may be expressed as nv and neutrons per cm² as nvt.

mechanical properties are given in Table 2.

The welding electrodes used were the cellulose-type electrode, AWS E7010 and the low-hydrogen-type electrode, AWS E7016. The manufacturer's specified chemical analysis and mechanical property ranges are given in Table 3.

Outline of Test

ASTM A212, Grade B pressure plate material was welded in the irradiated condition with both a cellulose-type and a low-hydrogen-type welding electrode. These welds were compared with unirradiated control test welds. Both types of welding rods were used because the propensity toward underbead cracking increases with hydrogen content. It is postulated that where possible radiation effects would not be severe enough to produce underbead cracking in test plates welded with the low-hydrogen-type electrode, the radiation effects may be severe enough to produce underbead cracking when the high-hydrogen cellulose-type electrode was used.

Welding was done by two welders, each welding the A212 material in the control and irradiated condition with the same type welding electrode. To assure that any difficulties encountered during the welding of the irradiated test plates were not due to the sequence of welding, the control test plates were welded first.

Prior to welding, the irradiated test specimens were radiated at Brookhaven National Laboratory to an integrated thermal flux of 10^{18} nvt. This is equivalent to the radiation received over a period of ten core lives in the vicinity of the pressure-vessel head-closure weld.

Weldability of the irradiated A212 material was investigated by (1) circular-bead underbead-cracking test, (2) tee-bend, and (3) modified Navy "torture" test. In these tests, fillet, butt and cladding-type weld deposits were studied.

All weld joints were inspected for possible defects in the weld or adjacent base material. Magnetic-particle inspection was used in conjunction with the dye-penetrant method to inspect the circular-bead underbead-cracking test after machining. All fillet welds were dye-penetrant inspected while the $1^1/_2$-in. butt welds were dye-penetrant inspected and radiographed.

After welding and inspection, the weldability tests were machined into test specimens for further testing. The tee-bend test was cut into five specimens and each bend tested in the standard tee-bend jig. Deflection and load at initiation of failure were noted as well as the extent and type of failure. The modified Navy "torture" tests were machined into tensile specimens, macro side-bend specimens, and notched and unnotched tension-impact specimens.

Table 3

Chemical analysis of welding electrodes

Electrode	*C*	*Mn*	*Si*	*S*	*P*	*Mo*
AWS E7010	0.07/0.10	0.45/0.60	0.10/0.20	0.035 (max)	0.030 (max)	0.50/0.60
AWS E7016	0.06	0.55	0.35	...	...	...

All-weld-metal mechanical properties

Electrode	*Yield, psi*	*Tensile, psi*	*Elongation, %*	*Reduction of area, %*
AWS E7016 (as-welded)	70,000	80,000	26.0	60
(1150° F stress relief)	62,000	75,000	30	68
AWS E7010 (as-welded)	66,000 (max)	82,000	25	...
	62,000 (min)	77,000	18	...

Irradiation

The irradiated test plates were irradiated at Brookhaven National Laboratory in Facilities W-13 and E-13 for a total of 769 megawatt-hours at a temperature less than 50° C. Time of irradiation was 30.5 hr at approximately 10^{11} nv or for a total of approximately 10^{18} nvt.

The cadmium ratios measured previously at the positions used in Facilities W-13 and E-13 were approximately 100 and 65, respectively. These are indicative of a high degree of thermalization which is anticipated at the reweld area of the pressure vessel.

Three of the test plates for the Navy "torture" test were irradiated in Facility W-13 while the fourth test plate was irradiated in Facility E-13. Both test blocks for the circular-bead underbead-cracking test were irradiated in Facility W-13. The remainder of the test plates used for the tee-bend test were irradiated in Facility E-13.

Radiation levels measured at the surface of the test plates were 50 mr/hr for the modified Navy "torture" test plates, 70 mr/hr for the circular-bead underbead-cracking test, and 85 mr/hr for the tee-bend test. The material was 2 in. thick, $1^1/_2$ in. thick, and $^1/_2$ in. thick, respectively.

Tests Performed and Results

Four series of tests were made as shown in Table 4. Two series were in the unirradiated or control condition while the other two were in the irradiated condition. The control and irradiated tests were welded with both the cellulose-type and low-hydrogen-type welding electrodes.

Each series of tests consisted of three weldability tests which in turn were machined into test specimens for further testing. The size of all test plates was limited by the radiation facility.

The Circular-Bead Underbead-Cracking Test

This test shown in Fig. 1 consisted of depositing a single bead of $^5/_{32}$-in. diam electrode in a $2^1/_2$-in. diam circle on both sides of a $1^1/_2 \times 3^3/_4 \times 4$-in. plate section. The first side was welded at room temperature and quenched in ice water immediately thereafter. After the test plate warmed up to room temperature the second side was welded and air cooled. Water quenching was used in addition to air cooling to further increase the propensity of the A212 material to underbead cracking. If cracking was noted in either of the irradiated test plates, it would be compared with the unirradiated control plate.

After completion of the welding phase the deposited weld bead was machined flush, a maximum of $^1/_{64}$ in. of the original plate surfaces were removed, and these surfaces were examined for underbead cracking. Both dye-penetrant inspection and magnetic-particle

Table 4—Number of Tests Performed to Test Weld Joint

	Unirradiated control		*Irradiated (flux 10^{18} nvt)*	
Type of test	*Series I Cellulose type*	*Series II Low hydrogen*	*Series III Cellulose type*	*Series IV Low hydrogen*
Circular-bead cracking test				
As-welded	1	1	1	1
Water-quenched	1	1	1	1
Tee-bend test	1	1	1	1
Bend specimen	5	5	5	5
Mod. Navy "torture" test	1	1	1	1
Macroetch	2	2	2	2
Side-bend	2	2	2	2
Tensile test	2	2	2	2
Tension-impact	4	4	4	4
Notched-tension-impact	4	4	4	4

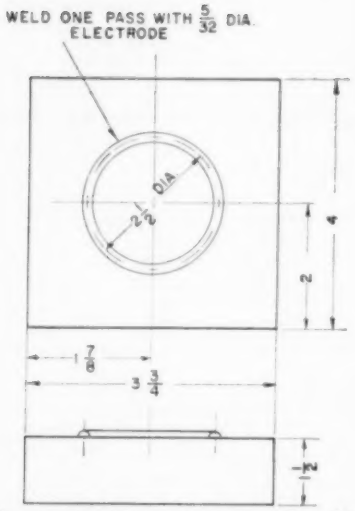
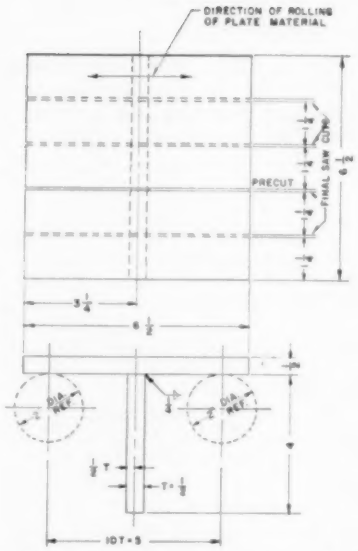


Fig. 1 Modified circular-bead weld underbead-cracking test


DIRECTION OF ROLLING OF PLATE MATERIAL
PRECUT
FINAL SAW CUT
6 1/2
3 1/4
6 1/2
1/2 T
T = 1/2
DIA. HOLE
DIA. HOLE
1 1/2
1 1/2
1 1/2

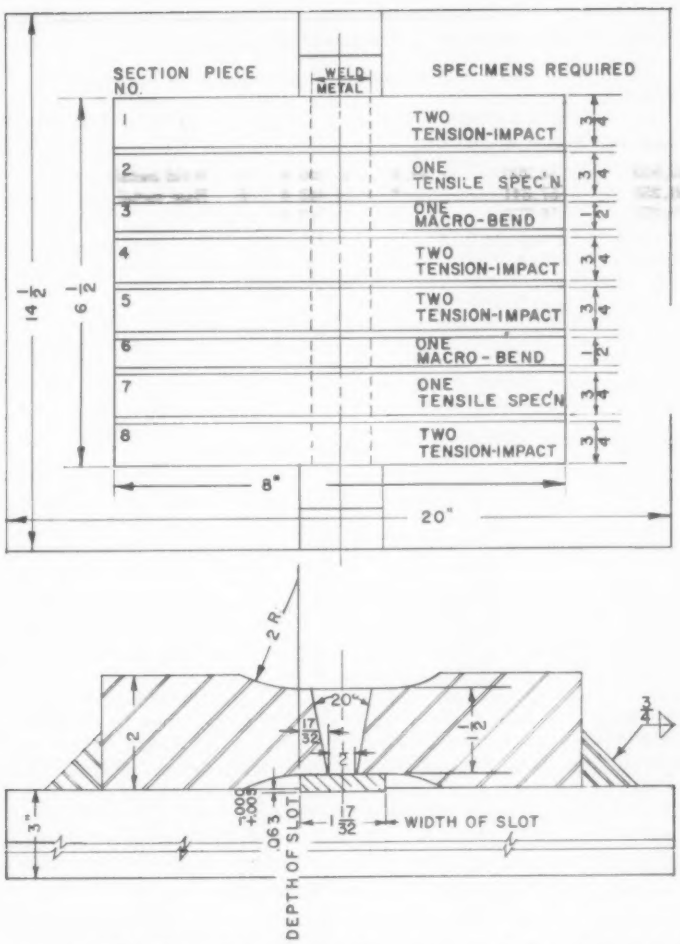


Fig. 3 Modified Navy "torture" test for testing irradiated plate material

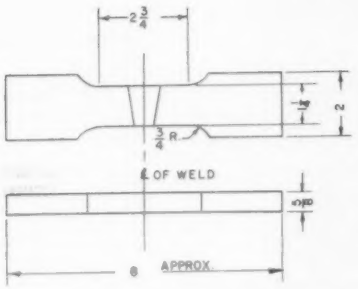


Fig. 4 Tensile specimen machined to permit failure to occur in weld or base material

radiographed in the undisturbed condition. A 2-in. wide backing strip was used so that its shadows would be outside that of the weld joint.

Only one of the four radiographs showed any evidence of entrapped slag. The remaining three were perfectly clear. Fortunately, the entrapped slag occurred in the unirradiated control weld joint welded with the low-hydrogen-type electrode. Thus, the presence of the slag was not due to a radiation effect but may be associated with the encumbrances of the welder with additional safety clothing and procedures.

After radiography, the modified Navy "torture" tests were sectioned for subsequent testing. The unirradiated test plate containing the entrapped slag had to be cut carefully to obtain the required number of unirradiated control test specimens.

Macro and Side-Bend Test

The side-bend test specimens were machined 1½ in. wide by ⅜ in. thick in accordance with Fig. 10 of Chapter 59 of the AWS Welding Handbook and bend tested on the guided-bend test jig as shown in Fig. 11 of the same reference.

Prior to bend testing, all eight side-bend specimens were macroetched with 10% nital on the side that would undergo compressive stresses during bending. All specimens etched identically. No difference could be detected between the irradiated and unirradiated control specimens. No evidence of underbead cracking, lack of fusion, or slag entrapment was evident in any of the etched specimens except those removed from the aforementioned unirradiated test plate. No defects were present in the irradiated specimens whether welded with the cellulose or low-hydrogen-type electrode.

Subsequent bend testing did not differentiate between the irradiated and control specimens. Both the irradiated and control side-bend specimens welded with the cellulose and low-hydrogen welding electrodes bent 180 deg without failure. A ⅛-in. corner weld crack was observed in specimens welded with the cellulose-type electrode in both the irradiated and unirradiated control condition. One small spot of weld porosity was observed in both of the unirradiated control side-bend specimens welded with the low-hydrogen electrode; no porosity was observed in the irradiated specimens, as shown in Table 6.

Tensile Test Specimens

The tensile test specimens shown in Fig. 4 contained the weld cross section and were machined so that failure would not be restricted to the weld deposit but could occur in the base metal or heat-affected zone. Two tensile specimens were pulled in each of the four conditions. Tensile testing was done at a strain rate of 0.5 ipm. The results of the eight tensile tests are given in Table 7.

Since the specimen was designed to permit failure to occur at the weakest point, failure did not always occur in the center of the reduced section between the gage marks. For this reason the percentage elongation was obtained on

Table 6—Side-Bend Test Specimens Welded A212 Material

Specimens	*Electrode AWS type*	*Degree of bend*	*Defects noted*
	Unirradiated control specimens		
299-3	E7010	180	None
299-6	E7010	180	⅛ In. corner crack in weld
301-3	E7015	180	1 Spot of porosity
301-6	E7015	180	1 Spot of porosity
	Irradiated specimens		
300-3	E7010	180	None
300-6	E7010	180	⅛ In. corner crack in weld
302-3	E7015	180	None
302-6	E7015	180	None

Table 7—Tensile Properties of Weld Joints in A212 Pressure Plate Material

Specimen No.	Electrode AWS type	Tensile, psi	Yield, psi, 0.2% offset	Elongation, % in 2 in.	Reduction of area, %	Location of failure
		Unirradiated control specimens				
M299-2	E7010	80,600	55,200	34.4	50.4	Weld metal
M299-7	E7010	80,253	57,341	*	43.4	Base metal
Avg		80,427	56,270		46.9	
M301-2	E7015	79,200	49,600	*	45.5	Base metal
M301-7	E7015	77,200	55,700	*	44.0	Base metal
Average		78,200	52,650		44.8	
		Irradiated specimens				
M300-2	E7010	80,400	56,300	35.9	50.3	Weld metal
M300-7	E7010	80,900	58,700	*	45.6	Base metal
Average		80,650	57,500		48.0	
M302-2	E7015	79,600	46,900	*	44.7	Base metal
M302-7	E7015	80,400	55,800	*	44.4	Base metal
Average		80,000	51,350		44.6	
Control grand average		78,300	54,500		45.9	All specimens failed with a ductile fracture
Irradiated grand average		80,300	54,400		46.3	

* Broke outside gage marks.

only two specimens. These specimens were removed from test plates welded with the cellulose-type electrode in both the irradiated and unirradiated conditions. The remainder of the tensile specimens failed in the base material. All specimens failed with a ductile-type fracture.

The tensile properties revealed no apparent effect due to irradiation on the welded test joints whether welded with the cellulose or low-hydrogen-type electrode. The average values of all four tensile tests from the irradiated test plates welded with both type of electrodes and the four unirradiated control specimens are given at the bottom of Table 7. Any variation is well within the normal spread encountered in tensile testing.

Tension-Impact Test Specimen

Both the standard ASTM, Type V, unnotched tension-impact specimen and a modified ASTM, Type U, multiple notched tension-impact specimen were used to evaluate the impact properties of the $1^1/_2$-in. thick weld joint. As shown in Fig. 5, the multiple notched tension-impact specimen subjects the entire heat-affected zone, weld metal, and base metal to notched impact loading. As a result, failure occurs in the weakest area. By comparing the results of the notched versus the unnotched specimens in both the irradiated and the unirradiated control conditions, the effects of irradiation on both impact strength and notch sensitivity under impact loading may be evaluated.

On the average, four tension-impact specimens were tested in the notched and unnotched conditions, welded with cellulose and low-hydrogen welding electrodes, and in the irradiated and unirradiated control conditions. The results are tabulated in Table 8.

Examination of the fractured surfaces of the tension-impact test specimens showed no embrittling effect due to irradiation. All the unnotched specimens failed in a completely ductile manner whether removed from the irradiated or from the unirradiated control test weld joints. The percentage of ductile failure in the notched control specimens welded with the cellulose and low-hydrogen-type electrode was 85 and 13%, respectively, and those removed from the irradiated test plates were 100 and 25%, respectively. The percentage of ductile failure in the irradiated condition was 12 and 14% higher than in the unirradiated control condition.

All tension-impact specimens welded with the cellulose-type electrode failed in the weld. Those welded with the low-hydrogen-type electrode failed in the base metal in the unirradiated control specimens; in the irradiated condition, half of the specimens failed in the base metal and half in the weld metal.

Discussion

A review of the data shows that no

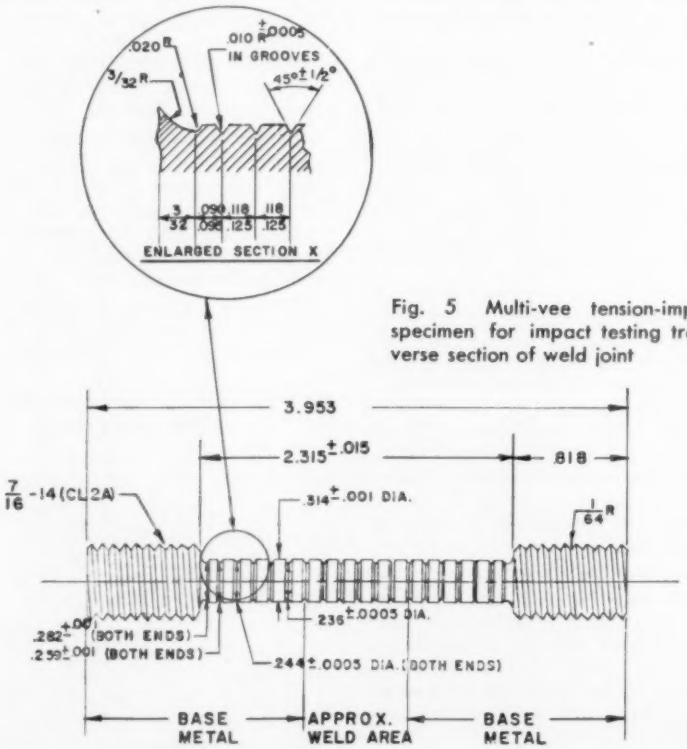


Fig. 5 Multi-vee tension-impact specimen for impact testing transverse section of weld joint

Table 8—Tension-Impact Strength of Welded A212 Material

Welding rod	Unnotched: Section No.	Ft-lb	% Ductile fracture, %*	Failure location	Multiple notched: Section No.	Ft-lb	% Ductile fracture, %	Failure location
			Unirradiated control specimens					
E7010	299-4	124	100	Weld	299-1	97	75	Weld
E7010	299-4	116	100	Weld	299-1	94	95	Weld
E7010	299-5	113	100	Weld	299-8	85	95	Weld
E7010	299-5	101½	100	Weld	299-8	87	80	Weld
Avg		114	100			91½	86	
E7015	301-4	112½	100	Base	301-1	97	10	Base
E7015	301-4	113	100	Base	301-1	99	20	Base
E7015	301-5	106	100	Base	301-8	...	10	Base
E7015	301-5A	138	100	Base	301-8	102½	10	Base
E7015	301-5A	107	100					
Avg		115	100			100	13	
			Irradiated specimens					
E7010	300-4	109	100	Weld	300-1	104	100	Weld
E7010	300-4	134½	100	Weld	300-1	95½	100	Weld
E7010	300-5	111½	100	Weld	300-8	92	100	Weld
E7010	300-5	129	100	Weld	300-8	97½	100	Weld
Avg		121	100			97½	100	
E7015	302-4	133	100	Base	302-1	80	70	Weld
E7015	302-4	112½	100	Base	302-1	134	10	Weld
E7015	302-5	125½	100	Weld	302-8	96	10	Base
E7015	302-5	123½	100	Weld	302-8	126	10	Base
Avg		124	100			109	25	

* Per cent ductile fracture was estimated visually.

difficulties were encountered during the welding or subsequent testing of irradiated A212 pressure-plate material.

Irradiation

The total disturbance of the crystal lattice of the test plates should far exceed that anticipated in the reweld area of the pressure vessel. Exposure of the test plates to a higher integrated flux level was accomplished within a period of 30.5 hr at a temperature under 50° C. Comparing this exposure to the $2^1/_2$-yr exposure of the pressure vessel at operating temperature indicates that the probability of partial recovery of the pressure vessel greatly exceeds that of the A212 test plates. Ambient temperature of the reweld area is in the neighborhood of 225° C.

Weldability and Inspection

No evidence was found at the test radiation level to indicate a relationship between neutron flux and weldability. Mode of deposit, solidification, and ease of slag removal were the same during welding of both the irradiated and control test plates. Inspection of the weld joints during and subsequent to welding by dye-penetrant, magnetic-particle, and radiographic inspection revealed no evidence of lack of fusion, underbead cracking, or slag entrapment in any of the six irradiated weldability tests.

Rough calculations by the derived formula, $\log \tau = 15.2(10^3/T) - 26.4$ from data on pure iron crystals, indicate that the minimum temperature at which 50% recovery would occur in one-hundredth of a min would be approximately 350° C or approximately 400° C for complete recovery. Thus, if this formula can be extrapolated, it is probable that the heat-affected zone† resulting from a sojourn into the austenitic temperature range during welding will completely recover from radiation damage. It is this area adjacent to the weld which is most highly stressed during and subsequent to welding.

Macroscopic and Microscopic Examination

Visual examination revealed no change over the unirradiated macrosections.

Since no radiation effects were observed by M. Bleiberg[23] in A212 material exposed to 1000 times as much integrated thermal flux as investigated in the present report, no additional metallographic examinations were made.

Mechanical Properties of the Weld Joint

Mechanical testing of the weldability tests revealed no evidence of radiation damage. Prior irradiation had no significant effect on the strength of the weld joints. The results of the tensile tests removed from the modified Navy "torture" test were the same within experimental error in the irradiated and control conditions. The average strength of the tee-bend tests, however, was 6% lower in the irradiated condition. This lower strength was compensated for to a degree by the greater deflection required to initiate failure and by the apparent increased resistance to crack propagation. Under impact loading, strength of the weld joint in the irradiated condition appeared to be approximately 7 to 8% higher than in the control condition. Of the data obtained, the impact data lends itself best to statistical analysis. Analysis of the data presented in Table 8 indicates that the observed increase in impact due to thermal irradiation approaches significance at the 10% level. Thus, the results of the data indicate an increase but do not conclusively prove it. If actually the true averages of the irradiated and unirradiated data were the same, the spread of data was sufficient so that one of these two groups of data could appear to have a higher average value then the other once out of every ten experiments.

Ductility and notch sensitivity were not adversely affected by prior irradiation. Average values in both the irradiated and control specimens showed percentage elongation to be equal within experimental error. All side bends bent 180 deg without failing. Irradiated tee-bend specimens deflected approximately 4% farther than the control specimens before cracking. On the average, cracking propagated 90% through the control specimens and 80% through the irradiated specimens. Examination of fractured surfaces revealed that all tensile, tee-bend, and unnotched tension-impact specimens failed with a ductile-type fracture. Notched tension-impact specimens, however, indicated a slight increase in ductility in the irradiated condition. Similar indications were noted in the

† The heat-affected zone normally extends approximately ¼ in. from the line of fusion.

tee-bend specimens where notch sensitivity decreased slightly with irradiation. Of prime importance, however, is the fact that prior irradiation by an integrated thermal flux of 10^{16} nvt did not harm the mechanical properties of the weld joint.

Encumbrance of the Welder

The quality of the weld was dependent to a large extent upon the skill of the welder. However, welding under radiation conditions required additional safety clothing and a breathing mask which hampered visibility and freedom of movement. Every effort should be made to minimize such encumbrances to permit the welder to apply his skill to the best advantage.

Conclusions

Conclusions Based on Experimental Data

The following conclusions are based on an integrated thermal flux of 10^{16} nvt unless stated otherwise.

1. Prior irradiation by an integrated thermal flux of 10^{16} nvt did not affect the weldability of ASTM A212, Grade B, pressure-vessel material in the thicknesses tested. It is believed that thickness is not a critical variable with respect to radiation.

2. Room temperature properties of the base material and weld joints were not adversely affected by prior irradiation.

3. No relationship was detected between welding defects and prior irradiation.

4. No peculiar effects or transformations were observed.

5. Encumbrance of the welder and psychological effects of the presence of irradiation are much more likely to affect the quality of the weld joint than neutron bombardment of the crystal lattice.

Review and Conclusions Based on Literature Survey

6. Adverse radiation effects on mechanical properties are principally due to fast flux up to 10^{20} nvt.

7. The mechanics of radiation damage are due primarily to the displacement of atoms from their normal positions in the crystral lattice up to 10^{20} nvt fast flux.

8. Normal unfissionable materials should not be affected by transmutations or impurity atoms for 10 to 20 yr in an integrated fast flux of 10^{14} nv.

9. Recovery is the reversible process of radiation damage up to 10^{20} nvt fast flux and is dependent upon time and temperature for the return of interstitial atoms to their normal positions in the crystal lattice.

10. Recovery follows a self-diffusion-type formula and is dependent upon a process with an activation energy equal to that required for self-diffusion.

11. Any radiation damage of steel in the pressure vessel is of a reversible nature and is dependent upon neutron flux, time and temperature up to 10^{20} nvt fast flux.

12. Integrated flux obtained during short time exposure is representative of service conditions only when the anticipated recovery during service does not exceed the anticipated recovery during short time exposure.

13. To date such reactions as transmutations, decompositions and phase changes have not been encountered as serious radiation problems at neutron flux levels up to 10^{20} nvt.

14. The heat-affected zone resulting from the welding operation is free of prior radiation damage at flux levels up to 10^{20} nvt.

15. The freedom of the heat-affected zone from radiation damage increases the probability of producing sound welds in irradiated steel up to 10^{20} nvt fast flux.

16. Adequate thermalization of the neutron flux may not only prevent radiation damage but may improve original ductility up to 10^{20} nvt.

17. Initial recovery rate is proportional to the degree of radiation damage.

18. The degree of radiation damage due to fast flux reaches a saturation or equilibrium condition at irradiation levels under 10^{20} nvt fast flux.

19. This equilibrium is dependent upon a balance between the damage rate and the recovery rate up to 10^{20} nvt fast flux.

20. Under conditions of irradiation, equilibrium favors recovery at elevated temperatures while at lower temperatures equilibrium favors radiation damage.

21. At some integrated flux level, possibly 10^{20} nvt, an irreversible component may be added to the reversible radiation damage component.

Acknowledgments

The author wishes to express his appreciation to Messrs. J. R. Hunter, J. G. Christ and M. A. Golik for encouragement and assistance during the progress of this investigation, to Messrs. R. C. Westphal and R. H. Fillnow for cooperation in the use of hot laboratory facilities and for reviewing the draft of this report, and to Messrs. M. F. Corcoran and P. R. Sampson for welding the control and irradiated ASTM A212 test plates.

This work was financed by Atomic Energy Commission Contract AT-11-1-GEN-14.

References

1. Internal letter, WAPD-MA-1854, dated June 9, 1954; cc—AEC, E. S. Wolslegel; NRB, J. R. Nichels.
2. Hatfield, G. W., "Renovation of the N.R.X. Reactor at Chalk River, Ontario," WM-1. (To be used in conjunction with the moving picture film entitled "Restoration of the N.R.X. Reactor at A.E.C.L." Reels No. 1, 2, and 3). Chalk River, Ont., Mar. 12, 1954, p. 10.
3. Langmuir, David B., Memo to file "Welding Operations on the N.R.X. Thermal Shield," Dec. 11, 1953, p. 3.
4. Stephenson, Richard, *Introduction to Nuclear Engineering*, p. 58 (1954).
5. *Ibid.*, p. 49.
6. *Ibid.*, p. 67.
7. *Ibid.*, p. 41.
8. *Ibid.*, p. 233.
9. *Ibid.*, p. 230.
10. *Reactor Handbook*, Vol. 3, p. 635.
11. Billington, D. S., and Siegel, Sidney, "Effect of Nuclear Radiation on Metal," *Metals Progr.*, 848, 852 (December, 1950).
12. Wilson, J. C., and Berggren, R. G., "Radiation Effects in Pressure Vessel Materials and Welds," *WASH-276*, April 1955, p. 40.
13. *Reactor Handbook*, Vol. 3, p. 636.
14. *Ibid.*, p. 637.
15. Stephenson, Richard, *op. cit.*, p. 238.
16. *Ibid.*, p. 229.
17. Kunz, F. W., and Holden, A. N., "The Effect of Short Time Moderate Flux Neutron Irradiations on the Mechanical Properties of Some Metals," *Acta Metallurgica*, **2**, No. 6, 820 (November 1954).
18. Report on Metallurgy Section, *KAPL-1039*, September to November 1953, p. 34.
19. Wilson, J. C., and Berggren, R. G., "Effects of Neutron Irradiation in Steel," paper presented at the Annual Meeting of the ASTM, June 26, 1955, p. 29.
20. Kunz, F. W., and Holden, A. N., *op. cit.*, p. 817.
21. Stephenson, *op. cit.*, p. 231.
22. Meyer, R. A., "Influence of Neutron Bombardment and Strain Hardening on Notch Sensitivity of Mild Steel," *Jnl. Appl. Phys.*, **25**, No. 11 (November 1954).
23. Bleiberg, M. L., "Effects of Neutron Bombardment Upon the Properties of ASTM Type SA 212-B Steel," WAPD-RM-205, Feb. 1, 1954, pp. 11, 15.
24. Kunz, F. W., and Holden, A. N., *op. cit.* p. 818.
25. Wilson, J. C., *et al.*, *op. cit.*, p. 24.

APPENDIX

Calculation of Time for 50% Recovery from Radiation Damage

Let $X = (1/T) \times 10^3$ T in ° K

1. $\text{Log } \tau = [(\Delta \log \tau)/\Delta X]\, X + C.$
2. $\text{Log } \tau = \dfrac{0-5}{1.716-2.041} X + C = \dfrac{-5}{-0.325} X + C$, values read from curve of Fig. 3, Reference 24.
3. $\text{Log } \tau = 15.2\, X + C.$
4. Let $\tau = 10^5$, then $X = 2.041$, values read from curve of Fig. 3, Reference 24.
5. $5 = 31.4 + C$, values in line 4 substituted into line 3.
6. $C = -26.4.$
7. $\text{Log } \tau = 15.2\, X + C.$
8. $\text{Log } \tau = 15.2\ (10^3/T) - 26.4$, substituting values of X and C into line 7.

Calculation of Time for Recovery at 175 and 225° C

Let T = 175 and 225° C, then T = 448 and 498° K. $10^3/T = 2.23$; $10^3/T = 2.01$

175° C	$\log \tau = 15.2(2.23) - 26.4$
225° C	$\log \tau = 15.2(2.01) - 26.4$
175° C	$\log \tau = 33.9 - 26.4 = 7.5$
225° C	$\log \tau = 30.6 - 26.4 = 4.2$
175° C	τ 175°C $= 3.2 \times 10^7$ min 55 years
225° C	τ 225°C $= 1.6 \times 10^4$ min 10 days

A COMPARATIVE STUDY OF THORIATED, ZIRCONIATED AND PURE TUNGSTEN ELECTRODES

Thoriated tungsten electrodes found to show superior starting characteristics when used for d-c straight-polarity welding of stainless steel

BY L. P. WINSOR AND R. R. TURK

SYNOPSIS. A comparative study has been made of the characteristics of thoriated, zirconiated and pure tungsten electrodes under both normal and abnormal welding conditions using both direct current and alternating current arcs in atmospheres of argon and helium. Thoriated-tungsten electrodes showed superior starting performance during d-c straight polarity welding of stainless steel, followed by zirconiated tungsten and pure tungsten in that order. Electrode consumption resulting from normal starting and evaporation was found to be negligible compared with loss caused by erosion from contamination introduced by the weld metal. Metallographic studies of the electrodes indicate that erratic arcing and the rate of erosion are both functions of the type of recrystallized structure existing in the electrode tip during welding. The formation of a ball of molten tungsten at the electrode tip during a-c welding of aluminum eliminated contamination of the electrode by the base metal.

L. P. Winsor is Professor of Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.; **R. R. Turk** was formerly Supervisor, Metallurgical Laboratory, Sylvania Elec. Products, Inc., Towanda, Pa., and is now Research Engineer, North American Aviation, Downey, Calif.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Introduction

A number of investigations have been made of the performance of pure-tungsten and thoriated-tungsten electrodes when used in inert-gas arc welding. The absence of such data for zirconiated tungsten led the authors to make a study of the comparable characteristics of all three electrode types. Starting performance, burning voltage, tip temperature, tip development and electrode consumption have been studied and evaluated. Special consideration has been given to electrode consumption due to contamination effects which was found to be far more significant in accounting for electrode loss than the evaporation losses previously reported.

Electrodes were $^1/_{16}$ in. in diameter, centerless ground. Workpieces were flat strips $1^1/_4$ by 18 by $^1/_{16}$ in. thick, clamped securely in specially designed jigs. Direct current studies were made with Type 304 stainless steel, ground No. 4 finish on one side, using straight polarity (electrode negative); alternating current studies were made on 2S aluminum with bright finish.

Direct-Current Welding

(a) Starting Characteristics

A comparison of the percent of successful starts as a function of open circuit voltage for the three electrode types is shown in Figs. 1 and 2 for high frequency and touch starting, respectively. Follow-up arc current was adjusted to approximately 100 amp in each case. Electrode tips were cut square with pliers.

Thoriated tungsten was found to start and hold an arc at the lowest values of voltage, followed by zirconiated tungsten and pure tungsten in that order. The minimum starting voltages for both thoriated and zirconiated tungsten are fairly definite while that for pure tungsten is much more random. Arc initiation with thoriated tungsten is always positive in nature while incomplete starts are frequently encountered with zirconiated and pure tungsten at the lower voltages. Touch starting gives both lower and less random starting voltages. Pointing the electrodes tends to

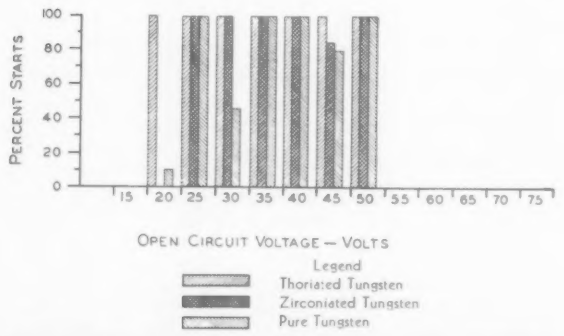


Fig. 1 Percent successful starts—flat-ended electrodes, high-frequency starting

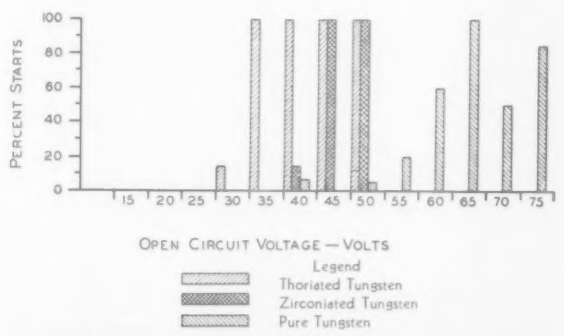


Fig. 2 Percent successful starts—flat-ended electrodes, touch starting

Table 1—Temperature Distribution Along Electrode*

Distance from tip	*Temperature,° C*
At tip	2925
Half diameter	2745
One diameter	2690
Two diameters	2440

* Pure tungsten electrode—argon. Current, 100 amp; travel speed, 10 ipm.

bring the starting voltages for thoriated and zirconiated tungsten closer together, but produces relatively small change in the results for pure tungsten. Results in helium are comparable to those in argon except for an increase in the minimum starting voltages.

It may be significant to note that the order of the electrodes for increasing starting voltages corresponds to the order for the increasing work functions of the electrode additives.

(b) Arc Voltage

The choice of gas is a major factor in determining the arc voltage. In helium the burning voltage is of the order of twice the voltage in argon at a current of 60 amp, decreasing to approximately three-halves as much at 150 amp. This is to be expected from the greater ionization potential for helium. The current has a relatively smaller effect on burning voltage, causing the voltage to increase with an increase in current in argon and decrease with an increase in current in helium over the same current range of 60 to 150 amp. The voltage varies with the choice of electrode, increasing in the same order as for the starting voltage, as predicted from the order of increasing ionization potential.

(c) Electrode Temperature

A summary of tip temperature measurements, as determined by a micro-optical pyrometer, is shown in Tables 1, 2 and 3. Table 1 shows an average temperature gradient of 3900° C per inch in argon over the first $^1/_8$ in. of electrode length. Because of the fairly uniform temperature gradient, most measurements were made at a distance of one-half diameter ($^1/_{32}$ in.) from the tip. The tip temperature for pure tungsten was found to be approximately 500° below the mp although it is possible that the hot spot was shielded from the instrument. Comparable temperatures were found for zirconiated tungsten while thoriated appeared to run definitely cooler. No significant trend was discernable with change in arc current over a range between 80 and 120 amp (Table 2) or with change in travel speed over a range from 8 to 13 ipm.

The random fluctuation of the arc often introduced changes in tip temperature. This was especially pronounced with pure tungsten where the tendency of the electrode to ball often changed the shape of the electrode tip as well as the location of the cathode spot. Electrode contamination introduced appreciable temperature fluctuation, usually resulting in a lower temperature.

Table 2—Temperature Variation° C with Current*

	Arc current, amp		
Electrode material	*80*	*100*	*120*
Thoriated tungsten	.....	2575	..
	2640	2630	2650
Zirconiated tungsten	.....	2660	..
	2710–2800	..	..
	2690	2820	..
	.....	..	2740
Pure tungsten	.....	2745	..
	2850	..	..
	2680	..	..
	.....	..	2770

* Argon. Travel speed, 10 ipm. Temperature measured half diameter from tip.

Table 3—Electrode Temperature in Helium*

	Electrode temperature, ° C		
Electrode material	*$^1/_2$ diam from tip*	*Bright spot*	*Dark spot*
Thoriated tungsten	2720	2920	2560–2620
	2550	2940–3110	2290
Zirconiated tungsten	2790–2890	3060–3150	2840
Pure tungsten	3020–3140	.....	2840–2980

* Arc current, 100 amp. Travel speed, 10 ipm.

The electrode temperature was found to be slightly higher in helium than in argon, as shown by Table 3. During the first half minute of arcing, fairly consistent temperature gradients were observed and satisfactory temperature measurements could be made one-half diameter from the tip. Then the high temperature of the tip began to form a small projection on the edge of the electrode which developed into a hot spot. The temperature of the hot spot increased to a higher value than that previously measured while the rest of the tip became cooler. Exact temperature measurements became very difficult to make because of the sharp gradients existing.

(d) Electrode Consumption

A summary of comparative electrode losses in argon is tabulated in Table 4. Continuous welding for periods of 40 min at a current of 100 amp on a revolving length of stainless-steel pipe resulted in losses of 0.00030 and 0.00024 g of electrode material per foot of bead for thoriated and zirconiated tungsten, respectively. The average loss per foot was nearly doubled when a welding cycle consisting of a series of 2-in. beads was substituted for continuous welding. Since touch starting was employed, the additional loss is undoubtedly starting loss.

The loss due to touch starting alone was measured by alternately striking an arc and immediately extinguishing it. The average loss per start for one hundred such trials was found to be at least an order of magnitude higher than the additional loss per start determined during the cyclic welding. The increased loss can probably be attributed to the fact that the arc was initiated while the electrode was still hot during the starting loss measurements while it was always allowed to cool between beads during the cyclic welding. The starting loss is minimum with thoriated

Table 4—Electrode Loss*

	Direct current—straight polarity			
Electrode type	*Continuous welding, G/ft*	*Cyclic welding, G/ft*	*Starting loss, G/start*	*Contamination loss, G/dip*
Thoriated tungsten	0.00030	0.00051	0.00011	0.0011
Zirconiated tungsten	0.00023	0.00046	0.00084	0.0148
Pure tungsten	...	...	0.00124	0.0193

* Shielding gas, argon. Arc current, 100 amp.

Table 5—Electrode Consumption During Starting

Electrode	Loss in weight, g—With d-c component	Without d-c component
Thoriated tungsten	0.0039	0.0040
Zirconiated tungsten	0.0017	0.0014
Pure tungsten	....	0.0007

tungsten and increases with zirconiated and pure tungsten in that order. The loss was found to be appreciably greater in helium than in argon.

Caution should be used in interpreting loss data since the "loss" measured is the net difference between the electrode weights before and after arcing. When the electrode accumulates contamination from the weld pool, the loss in tungsten will exceed the measured loss by the amount of contamination. When the electrode consumption is small, as for thoriated tungsten, the error may be appreciable, and one case is on record where a negative "loss" was measured. When contamination becomes appreciable, however, erosion is accelerated and becomes a major source of electrode loss.

The effect of contamination on electrode loss was studied by periodically dipping the electrode into the molten pool and withdrawing it to restrike the arc while welding progressed in an otherwise normal manner. Thoriated tungsten exhibited the tendency to freeze to the work when dipped during automatic welding to such an extent that quantitative data could not be obtained. However, when manual welding was employed, a thoriated electrode could be dipped into the molten pool and withdrawn without serious adverse effects. The arc quickly regained stability, and no apparent loss of electrode material was observed. After many such dips, the tip of the electrode merely appeared roughened. When the hot electrode was allowed to touch the cold metal surrounding the pool, however, it froze every time. In comparison, a cold electrode could be dragged along the surface without difficulty even while the electrode heated up, and the arc could be struck whenever the electrode was lifted from the work. The tendency of thoriated tungsten to freeze to the cold work surface probably explains why a thoriated electrode was found more apt to freeze during touch starting than the other two electrodes.

With a zirconiated electrode, each contamination was followed by severe arc instability which continued for at least a full inch of travel. A pronounced change in the tip was observed after each contamination. Sometimes a small tip formed at the end of the electrode; other times it would be a globule. After three or four such contaminations, the entire tip would disintegrate, often shortening the electrode by as much as $^3/_{32}$ in. As soon as one ball disappeared, the entire cycle would repeat itself. Less difficulty with sticking was experienced than with thoriated, and sticking was usually less severe. However, when freezing did occur, the electrode would tend to neck down and break off $^1/_8$ to $^1/_4$ in. from the tip when it was pulled free while thoriated would normally break loose at the point of contact.

The effect of contamination was even more pronounced with pure tungsten, leading to even greater electrode consumption. Small bulbs or projections were often formed on the end of the electrode. Sometimes these were blown off while other times they would neck down sufficiently to short circuit the arc. Pure tungsten showed no tendency to freeze and a minimum tendency to stick when dragged over the cold work, and often an arc would be initiated when the electrode struck a rough spot or contact pressure was reduced. Results were similar for hot and cold electrodes.

Comparable loss measurements are included in Table 4. The data for thoriated tungsten represent the average loss for 125 dips while those for zirconiated and pure tungsten represent approximately thirty each. One inch of weld bead was laid between successive contaminations. Contamination loss is an entire order of magnitude higher for zirconiated and pure tungsten than for thoriated and in each case the contamination loss per contact is an entire order greater than the starting loss.

The results show conclusively that electrode loss due to touch starting, sticking and contamination far exceed the loss due to electrode evaporation encountered during stable continuous operation. The electrode loss due to the removal of the tip following contamination or freezing is equivalent to the loss from hours of continuous welding. In addition, the loss of operator time and the possibility of poor welds introduced through electrode contamination

Table 6—Ball Diameter

Electrode	Diameter, in.—With d-c component	Without d-c component
Thoriated tungsten	0.070*	0.130
Zirconiated tungsten	0.086	0.126
Pure tungsten	0.089	0.137

* Diameter of cone—no ball.

Table 7—Electrode Consumption During Welding*

Electrode	Electrode consumption—With d-c component g/ft	Without d-c component, g/ft
Thoriated tungsten	0.00198	0.00075
Zirconiated tungsten	0.00224	0.00055
Pure tungsten	0.00444	...

* Length of weld, 72 in.

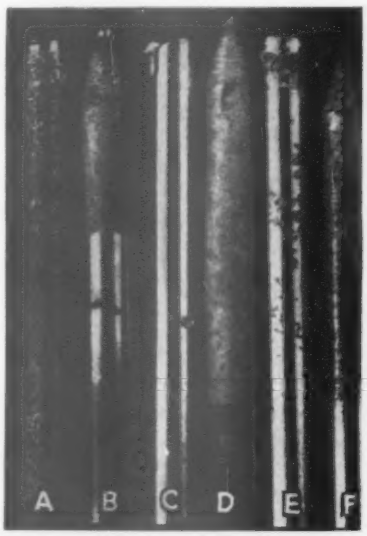


Fig. 3 External appearance of electrodes following arcing on direct current—A and B are pure tungsten, C and D are zirconiated tungsten, and E and F are thoriated tungsten. X5

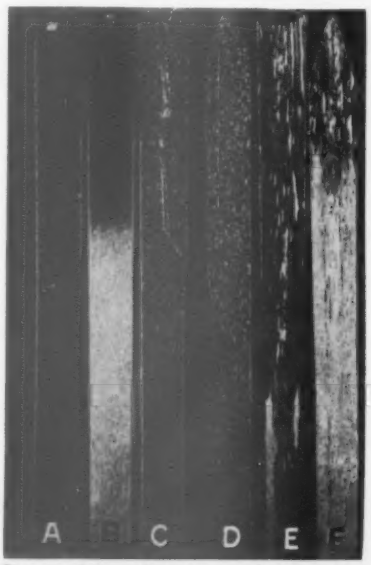


Fig. 4 Internal structure of electrodes in Fig. 3. X5

must not be overlooked in an over-all electrode evaluation.

Alternating-Current Welding

In alternating-current welding, partial rectification introduces an appreciable direct current component into the arc current. A simple D'arsonal ammeter is sufficient to measure the d-c component. The measurement of the a-c component is somewhat more difficult since the d-c component prevents the use of a current transformer. For this investigation, a specially built thermocouple ammeter, filtered and shielded to eliminate radio-frequency pickup from the stabilizing circuit, was employed to measure the total effective value of the arc current. The a-c component was calculated by taking the square root of the difference between the squares of the other two measurements.

The d-c component was found to be of the order of 50% of the a-c component up to an a-c component of approximately 100 amp. Above 100 amp, the d-c component decreased in both percent and absolute value. For some measurements, the d-c component was practically eliminated by bucking it with a storage battery. Eight volts were normally employed although six volts proved satisfactory at the higher currents.

(a) Starting Characteristics

High-frequency stabilization was used throughout so that touch starting was unnecessary. The electrode was found to behave entirely differently on ac than on dc. When the d-c component of the current is eliminated, all three electrodes form a ball of molten tungsten at the tip almost immediately following arc initiation. The balling is accompanied by an increase in gap length of $^1/_4$ to $^5/_{16}$ of an inch. Relatively little electrode material is lost as evidenced by Table 5; the electrode merely balls up and recedes into the cup. When the gap is reset, little further change in electrode appearance or gap length is observed.

The diameter of the ball is of the order of twice the electrode diameter and slightly greater at 120 amp than 100 amp. The presence of the ball seems to be characteristic of satisfactory operation and good weld penetration is not obtained until it forms. When the d-c component of the current is retained, a similar although smaller ball is produced with both zirconiated and pure tungsten. In contrast, the thoriated electrode forms a pointed or conical tip of molten tungsten at the very end. Typical values of ball diameter are shown in Table 6.

(b) Electrode Consumption

Measurements of electrode consumption during alternating current welding are summarized in Table 7. The electrode loss in the absence of the d-c component to the current is comparable to that measured on direct current (Table 5). When the d-c component is retained, the loss is increased by a factor of about three. The increased loss may be due partly to the increased value of the current as well as to the effects of the d-c component itself. Pure tungsten exhibited about twice the loss of thoriated and zirconiated tungsten.

(c) Electrode Contamination

In alternating-current welding on aluminum, all three electrodes seem to be much more susceptible to freezing than for direct-current welding on stainless steel. This is probably due to the high thermal conductivity of the aluminum workpiece. The molten tip is highly mobile and for short gap lengths often elongates sufficiently to freeze to the work.

Dip contamination tests were impossible because of the susceptibility to freezing. When the electrode was dipped momentarily or partially into the pool, negligible disturbance was observed. Normal arc stability was regained almost immediately and the electrode tip assumed its normal appearance.

Metallographic Studies

(a) Tip Structure

Pointing the electrodes was found to lower the voltage at which a stable arc could be struck, as compared with square cut electrodes. Of the three electrode types used for d-c welding, thoriated tungsten retained its pointed tip longest and showed the greatest resistance to contamination and erosion. Pure tungsten was poorest in these respects while zirconiated tungsten was found to be intermediate.

Figure 3 shows a comparison of the external appearances of some typical electrodes following normal d-c arcing in argon on stainless steel. Figure 4 contains photomicrographs of the internal structures of the same electrodes. Samples (*a*) and (*b*) are pure tungsten, (*c*) and (*d*) are zirconiated tungsten and (*e*) and (*f*) are thoriated tungsten. Cracking of some samples occurred during metallographic preparation. The shattering produced within the highly crystallized tips of electrodes when they are cut or ground is a major source of electrode loss.

The tips of both pure tungsten electrodes were shiny, suggestive of molten tungsten. The large grained structures of the extreme tips bear this out. Note the dull matte finish on the three pointed samples and how it seems to correspond to the recrystallized portions of the elec-

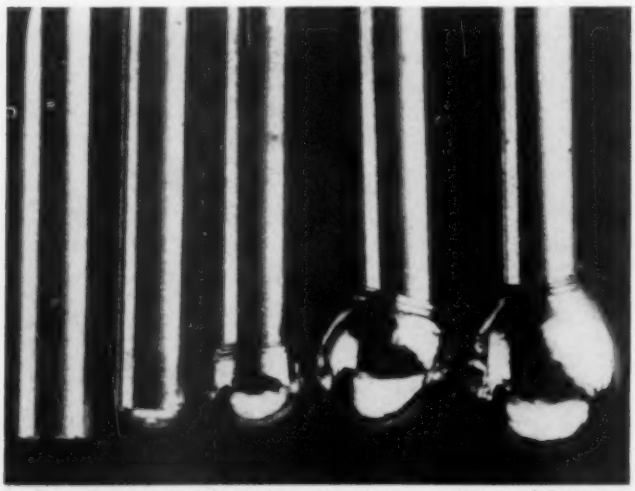


Fig. 5 Progress of ball formation in a-c welding. (1) Unused electrode, (2) after initial arcing, (3) after 1 second arcing, (4) after 2 seconds arcing, (5) after 4 seconds arcing. X 10

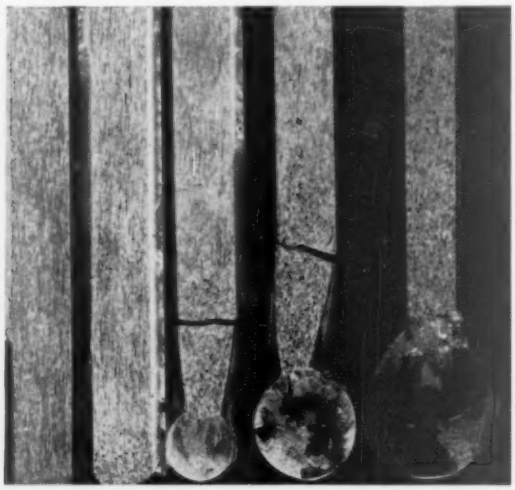


Fig. 6 Internal structure of electrodes in Fig. 5. X 10

Fig. 7 Zirconiated-tungsten electrode showing steel adhering to the tip. X 10

trodes. The shorter recrystallized zones for thoriated and pure tungsten indicate most of the heat was concentrated near the tip in these cases. This is probably due to the limited area for movement of the cathode spot (arc source) and small cross section for heat conduction along the electrode. Square cut electrodes show a more extensive region of recrystallization since there is less restriction to heat flow along the electrode.

The recrystallized structure is coarsest for the thoriated, intermediate for zirconiated and finest for pure tungsten. The apparent resistance of thoriated tungsten to contamination and erosion may be due to the fewer grain boundaries to be attacked. Photomicrographs at high magnification show that thoriated and zirconiated inclusions tend to coarsen and spheroidize as the hotter zone is approached. The flat-ended thoriated electrode shows three distinct zones—a section strongly cored and segregated, possibly having been molten or having steel pickup; a larger second section showing a definitely oriented precipitated phase (more than 1% if it were thoria) which disappears toward the cooler end of the region; and finally a coarse fibrous area exhibiting inclusion strings typical of a thoriated rod. Pure tungsten at the same magnification shows only an equiaxed structure at the same distances from the tip.

Typical of alternating-current welding is the formation of the molten tungsten ball at the tip of the electrode almost immediately following arc initiation. The ball formation, giving a tip of broad area, provides a wide, heat-distributing arc which is excellent for the welding of high-conductivity metals such as aluminum. Zirconiated tungsten, with its readiness to form a ball of large diameter, is frequently considered superior to other electrode types for alternating current welding.

Figures 5 and 6 illustrate the progress of ball formation with zirconiated-tungsten electrodes during a-c welding of aluminum in argon (breakage in photographs is due to metallographic preparation). Note the increasing extent of recrystallization of the structure (coarse grains, nonfibrous) as the time of arcing increases and the ball, or heat source, grows in size. Alternating-current arcing is found to produce a much more extensive region of high temperature penetration along the electrode than direct-current arcing.

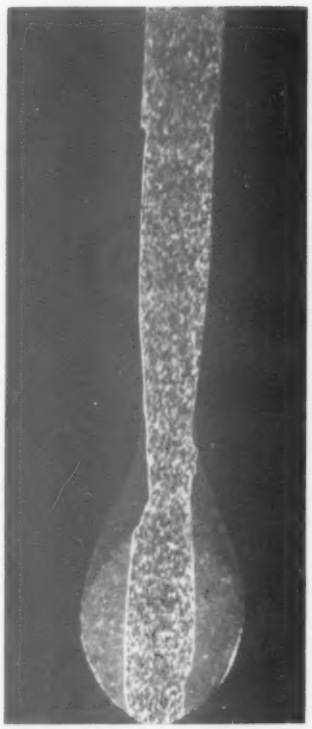


Fig. 8 Internal structure of tip in Fig. 7. X 10

(b) Erosion of Tungsten

Contamination of the tungsten electrode by molten steel from the workpiece was common during d-c welding. Similar contamination was not produced during a-c welding of aluminum.

The build-up of steel contamination on a zirconiated-tungsten electrode is illustrated in Fig. 7. The erosion of the tungsten by the steel is clearly exhibited in Fig. 8. Note that the steel ball sur-

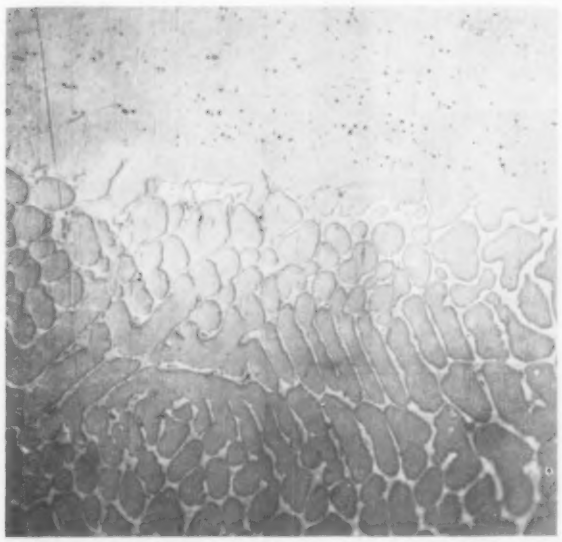


Fig. 9 Tungsten-steel interface of electrode in Fig. 7. Nital etch. X 650

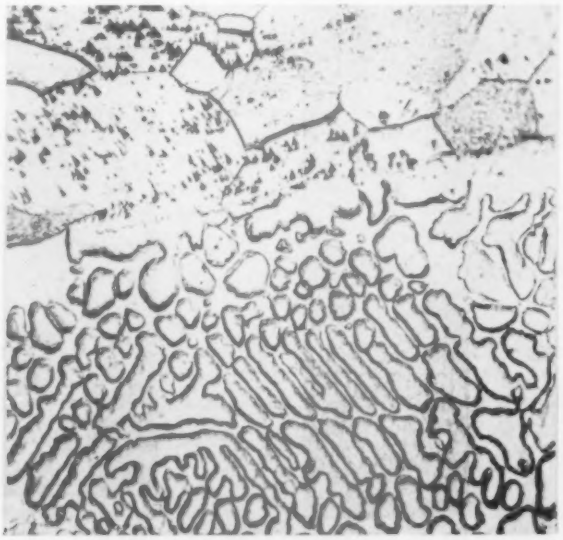


Fig. 10 Tungsten-steel interface of electrode in Fig. 7. Same area as Fig. 9. Potassium ferricyanide etch. X 650

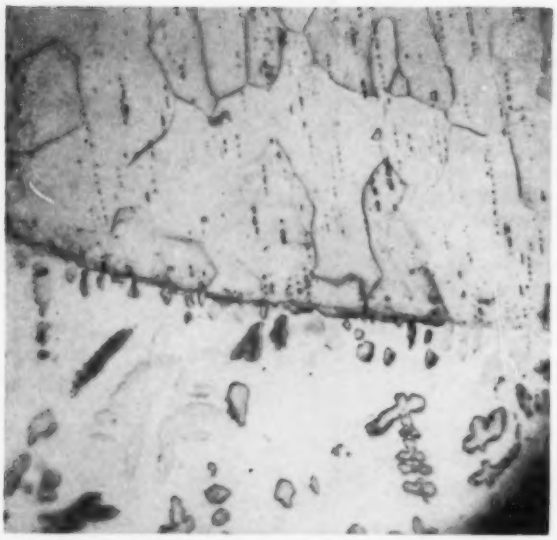


Fig. 11 Metallographic structure of interface between tungsten and steel (lighter color) at tip end of zirconiated-tungsten electrode. X 1000

Fig. 12 Metallographic structure of interface between tungsten and steel one-eighth inch from end of zirconiated-tungsten electrode. X 1000

rounding the electrode is darker toward the end of the ball away from the arcing tip. This end of the ball, producing the maximum erosion of tungsten, appears to have the ideal temperature conditions for tungsten solution. Details of the surface of the electrode in this region are shown in Figs. 9 and 10. The nital etch brings out the steel while the potassium ferricyanide etch emphasizes the tungsten. Note how the steel penetrates the tungsten, causing the tungsten to dissolve into the steel.

Erosion appears to be somewhat dependent on the orientation of the metal crystals involved, occurring more rapidly from the sides of an electrode than the end. Figures 11 and 12, taken respectively at the tip and approximately one-eighth inch from the tip of a zirconiated-tungsten electrode bear this out. Note how the tungsten is dissolved into the steel. Extensive erosion was often the cause of erratic arcing. Figures 13 and 14 show how erosion had continued until a piece of tungsten had become detached from the electrode and dropped to the bottom of the molten steel ball. This tungsten protrusion from the ball afforded an excellent source for a cathode spot. Unfortunately, however, the extreme mobility of the ball to which it was suspended often allowed the tip to be whipped around to many positions, producing erratic arcing. Figure 15 demonstrates how erosion was increased when the electrode was dipped into the pool for accelerated contamination tests. Such erosion not only leads to erratic arcing but is the major factor in determining electrode loss as well.

Fig. 13 Tip of zirconiated-tungsten electrode which exhibited erratic arcing. X 3.5

Fig. 14 Microstructure of electrode of Fig. 13, showing detached piece of tungsten at tip of steel ball. X 40. (Reduced by $^1/_3$ upon reproduction.)

Summary

Thoriated-tungsten electrodes exhibited superior starting characteristics when used for d-c welding on stainless steel. Pointing improved the ease of starting with all three electrode types.

The shielding gas was the major factor

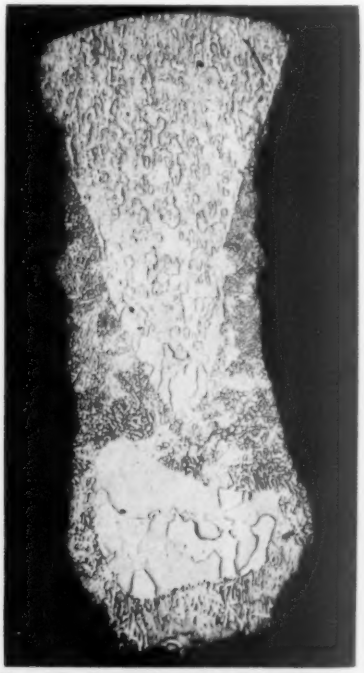


Fig. 15 Internal tip structure of electrode partially eroded by accelerated contamination

in determining arc voltage. Arc current and electrode material showed lesser effects.

Temperature measurements during d-c welding indicate that thoriated-tungsten electrodes operate somewhat cooler than zirconiated and pure tungsten. Electrodes operate hotter during a-c welding, leading to molten tungsten tips.

Electrode consumption is chiefly a function of contamination losses, other sources of loss being negligible by comparison. A coarse, long grained recrystallized electrode structure (found in thoriated tungsten) was found to be most resistive to erosive effects on d-c welding, and to retain a pointed tip best. Arc instability was traced to eroded tungsten pieces in steel pickup following contamination of the tip.

Acknowledgment

The arc investigation was carried out at Rensselaer Polytechnic Institute under contract with Sylvania Electric Products, Inc. The metallurgical studies of the electrodes were made at the Metallurgical Laboratories of Sylvania Electric Products, Inc.

The authors wish to acknowledge the assistance of Reuben Merchant who obtained the arc welding data, Robert Meister, formerly of Sylvania Electric Products Inc. (now a graduate student at Rensselaer Polytechnic Institute) who made the temperature measurements, and Harold Davidson of Sylvania who prepared the photomicrographs.

Bibliography

Huff, H. A., Jr., and Kugler, A. N., "Practical Aspects of Inert-Gas Welding," THE WELDING JOURNAL, **28** (2), 128–140 (1949).

Tuthill, R. W., "Tungsten: To Save or Not to Save," *Welding Engr.*, **34**, 42–45 (1949).

Urbain, G., "Measuring the Tungsten Consumption in Inert Gas Arc Welding," THE WELDING JOURNAL, **30** (5), Research Suppl., 260-s to 264-s (1951).

Gibson, G. J., and Seitz, R. O., "Thoriated-Tungsten Electrodes—Their Welding Characteristics and Applications," *Ibid.*, **31** (2), 102–108 (1952).

AUSTENITIC WELDS IN TYPE 502 STEEL PIPING

by H. G. Geerlings and W. P. Kerkhof

This company began its study of welded Type 502 steel in 1935, and tested the NCT3 (25% Cr – 20% Ni) electrode which was introduced by Krupp about that time. Good results were obtained but four difficulties were encountered: (*a*) hard heat-affected zone; (*b*) difference in coefficient of expansion between weld and pipe; (*c*) change in structure of the weld in service; (*d*) tendency of the weld metal to crack.

This paper discusses Type 502 piping with particular reference to points *a* to *d*. The Asiatic Petroleum Co. questioned seven firms (three electrode manufacturers and four fabricators) and found that a little less than 5% of the Type 502 welding was being done with austenitic electrodes. The authors' 20 years of experience show, nevertheless, that austenitic electrodes are better than Type 502 electrodes where accurately controlled heat treatment is impossible, as in field welding. Where heat treatment is possible (above AC3 or at 1325–1375° F) Type 502 electrodes are preferred.

The composition of the materials used in the experimental work is shown in Table 1.

Table 1—Composition, %, of Type 502 Piping and Austenitic Weld Metal

	C	*Cr*	*Ni*	*Mo*	*Cb*	*Mn*	*Si*
Pipe	0.16	4.9	...	0.70	...	0.39	0.25
Unstabilized weld metal	0.11	24.1	18.8	...	...	1.70	0.42
Stabilized weld metal	0.10	23.6	19.0	...	1.1	1.84	0.66

Hardness tests were made on Type 502 quenched from several temperatures (800 to 1200° C) and tempered for times up to 1000 hr at 500 and 550° C. The higher tempering temperature softened the steel more rapidly than the lower temperature. Charpy-V impact tests showed fairly good results even after quenching and that preheating to 482° F resulted in 25% higher Charpy value than without preheat. After 10,000 hr at 1292° F very coarse ferrite grains were observed in the heat-affected zone, and carbon had diffused into the austenitic weld metal.

Comparison of Type 310 electrodes from several suppliers showed that the weld metal composition varied a great deal among different brands: 22.6–25.1% Cr, 15.3–21.4% Ni, 0.03–0.83% Mo, 0.39–1.4% Si, 0.94–4.2% Mn. These variations represented different concepts in preventing hot cracks and assuring stability at elevated temperature. Hardness tests on weld metal after heating up to 10,000 hr at 932–1292° F showed that dispersion hardening occurred in unstabilized deposits, and that sigma phase appeared in the microstructure of stabilized deposits.

In two cases of pipes removed from Dubbs furnaces, cracking occurred due to sigma. The weld metal was 183–237 Vickers pyramid and 14 ft-lb Charpy V after 3200 hr of service. After being quenched from 2100° F, the Charpy value was 79 ft-lb. This weld contained 23.8% Cr, 18.4% Ni. In the second case, which had 50,000 hr of service the weld contained 23.0% Cr, 18.0% Ni and 0.81% Mo. The hardness was 185–204 and the Charpy V value was 10 ft-lb, which rose to 44 ft-lb after quenching. Microscopic examination revealed carbide precipitation and sigma phase.

A chart showing permissible stresses for various temperatures makes it clear that austenitic welded Type 502 piping can be used at service temperatures up to about 950° F.

Abstract by **Gerald E. Claussen,** Linde Air Products Co., of "Het Lassen van 5% Cr – 0.5% Mo Stalen Pijpen Met Austenitische Elektroden," published in *Lastechniek*, **22**, 176–181 (November 1956). The authors are associated with the Royal Shell Group, Amsterdam, Holland.

EFFECT OF PLASTIC FATIGUE ON PRESSURE-VESSEL MATERIALS AND DESIGN

Data developed through research projects at three universities have been correlated to establish the parameters governing pressure-vessel design with respect to the plastic fatigue characteristics of the material

BY L. F. KOOISTRA

ABSTRACT. In 1948 the Pressure Vessel Research Committee undertook a study on the possibility of increasing design stresses in pressure vessels. This led to an investigation of the effect of plastic fatigue on pressure-vessel materials and design. This paper is a summary of the work done on this problem at Lehigh University, the University of Illinois, École Polytechnique and The Babcock and Wilcox Co. The data have been correlated to establish the parameters governing pressure-vessel design with respect to the plastic fatigue characteristics of the material. Testing methods have been evaluated for determining "Plastic Endurance" as a characteristic of the material itself, as well as methods for establishing the "Effective Strain Concentration Factor" of various plate surface conditions, notches, attachments and the effect of welding. General conclusions for the practical application of the findings toward setting up safe design limits, as well as recommendations for further research, are presented.

Introduction

All existing codes governing the construction of boilers and unfired pressure vessels in the United States stipulate design stresses which are proportional to the ultimate tensile strengths of the materials used. The ratio of the tensile strength to the design stress is often referred to as the factor of safety. Long and successful experience with a factor of 4 has essentially outmoded the factor of 5 that governed pressure vessel construction for many years.

The yield strengths of the mild-carbon steels commonly used have been approximately 50% of their ultimate strengths. Hence, a factor of 4 based on ultimate has represented a factor of about 2 based on yield. While there has been some discussion about whether yield strength might be the more logical criterion, there has never been sufficient incentive to make the change so long as only mild-carbon steels were in general use.

As the art of steelmaking progressed, however, high-tensile steels were developed in which the ratios of yield to ultimate have been materially increased. There are steels available today which have yield strengths as high as 90% of their tensile strengths. Such steels cannot be utilized economically so long as the allowable design stress is limited to 25% of tensile strength.

It was this situation that led the Pressure Vessel Research Committee of the Welding Research Council in 1948 to undertake a study on the possibility of using increased design stresses in pressure vessels under certain limiting conditions to be determined. All divisions of PVRC have contributed and are continuing to contribute to this project.

Under the guidance of the Design Division, methods for the analytical determination of stresses and strains in boundary and junction regions are being developed. The experimental stress analysis work conducted at Purdue University has supplied correlative confirmation to the theoretical analyses performed to date.

The Materials Division has completed a literature survey of high-strength steels available here as well as abroad. This group has also sponsored, at Lehigh University, a series of tests to determine such mechanical properties as tensile strength, yield strength, ductility and transition temperature for a limited and selected group of high-strength steels. In addition, the Materials Division has arranged with the Chicago Bridge & Iron Co. for the development of welding procedures for this same group of steels.

The Fabrication Division undertook to study the effects of fabricating operations on fatigue properties of both mild and high-strength steels. This portion of the program originally consisted of tests of plate specimens at Lehigh University and pressure-vessel models at École Polytechnique. Later, for convenience in administering the work at Lehigh University, the Fabrication Division assumed responsibility for the study of fatigue properties of six high-strength steels at the request of the Materials Division.

In addition to these divisional activities, a Committee on Increased Design Stresses was created and made directly responsible to the Executive Committee of PVRC. This committee initiated a series of biaxial fatigue studies on full-thickness plate at the University of Illinois.

When it became apparent that the fatigue studies at Lehigh University, École Polytechnique and the University of Illinois needed closer coordination, the Committee on Increased Design Stresses was made a part of the Fabrication Division's related activities.

In September 1953, the Fabrication Division created the Coordinating Committee on Plastic Fatigue Strength for the purpose of correlating this experimental work. It is the report of this Coordinating Committee that is presented here. It is a summation of general results obtained. More specific details on the various experiments and conclusions are to be found in the technical papers that have been published on this work. These are listed in the references.

L. F. Kooistra is Superintendent, Materials Research, The Babcock & Wilcox Co., Alliance, Ohio.

To be presented at the 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Importance of Plastic Fatigue Resistance

It might be well to comment on the prominence given to fatigue testing in the over-all program of the PVRC. The records show that, in the beginning, this question was thoroughly considered and it was recognized that fatigue strength had been of relatively minor importance in pressure vessel failures.

It is a well-known fact, however, that at points of stress concentration, such as those adjacent to openings, supports, knuckles, etc., the local stress may be several times the membrane stress for which the vessel is designed. There also is a wealth of evidence and experience to show that vessels built from notch ductile materials will not fail under static loading at a pressure below the initial test pressure. It was recognized, however, that failure could take place at such pressures if the vessel was loaded and unloaded often enough, and in the event failure did occur, that it would be initiated at these points of stress or strain concentration. Under these circumstances the most probable cause for failure of a pressure vessel would therefore be repetitive and reversible straining of certain vulnerable parts of the vessel structure. If higher design stresses were to be allowed, utilizing a greater proportion of the tensile strength, such reversible strain would become the critical factor in the safety of the vessel.

It was, therefore, the consensus of those who initiated the Increased Design Stress Project, that fatigue strength was one of the important factors to be evaluated. It was also felt that, since the average pressure vessel is subjected to a low number of cycles during its life, the endurance limit is of little significance. It was decided, therefore, to concentrate on obtaining sufficient data to determine the cyclic strain ranges that would cause failure in less than 200,000 cycles.

Since relatively large strains are required to produce failure under these conditions, a large portion of the tests were conducted in the plastic range.

Brief Description of Tests Performed to Date at the University of Illinois, Lehigh University and École Polytechnique

The coordinated experiments at all three universities used steels from the same heats. The basic tests were conducted on ASTM A201 Grade A (a low-carbon steel) and ASTM A302 Grade B (a low-alloy high-strength steel). Other steels tested are A225, 48s5, Navy G, Fortiweld, NES70, J-Alloy-3 and T-1.

Realizing the probable difficulties in obtaining results that could be interpreted quantitatively, the steels were chosen to provide a qualitative comparison between the relatively new high-strength steels and a low-carbon steel (A201) with which there has been a great deal of experience. For the sake of completeness, a brief description of the testing methods used in the three laboratories follows. The specimens used in these tests are shown in Fig. 1. More exact detail can be obtained from the references listed at the end of this paper.

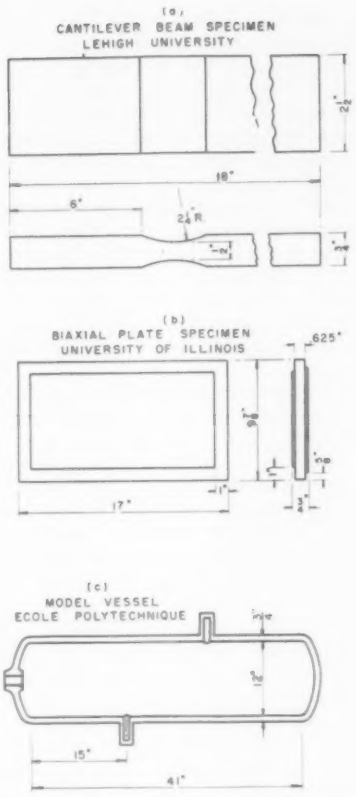


Fig. 1 Dimensions of the cantilever-beam, the biaxial-plate and the model-vessel fatigue specimen

Lehigh University

At Lehigh University, tests were performed on 2½-in.-wide plate specimens, loaded as cantilever beams (see Fig. 1*a*). Tests were conducted at constant deflection and cycled from zero to tension, or from equal tension to equal compression. A few tests were conducted on a constant-load machine in an effort to parallel the constant pressure tests at the University of Illinois and École Polytechnique. At Lehigh, the usual testing speed was 200 cpm, although tests have been run at other speeds for comparison.

It was found that, by properly proportioning specimen width to thickness, a biaxial stress system of 2-to-1 could be approached near the center of the test area because of the lateral restraint in the specimen. Failure was defined as complete fracture of the specimen.[1, 2, 3]

The University of Illinois

The testing device at the University of Illinois was adapted from a series of pilot tests performed by The Babcock and Wilcox Co.[4] Essentially it consisted of a piece of ¾-in. plate, approximately 9⅞ × 17 in. in size, fitted into a fixture that permitted hydraulic pressure to be applied to the bottom face of the plate. The plate was freely supported around the four edges. The test specimen is shown in Fig. 1*b*. The tensile stresses that developed in the central portion of the top face during loading were twice as large in the narrow direction of the plate as those in the longitudinal direction. Simulated nozzles, machined notches and welding were included in the various tests. The apparatus repeated a pressure cycle of zero to maximum at the rate of 100 cpm.

Failure was defined as the first crack on the metal surface to reach a length of 3/16 in.[5, 6, 7]

École Polytechnique

At École Polytechnique, small-scale pressure vessel models were tested. As shown in Fig. 1*c*, these vessels were 12 in. ID × 41 in. long between heads and were made of plates ¾ in. thick. They were subjected to cyclic pressures from zero to maximum at the rate of 3 to 40 cpm.

The first vessels were hydrostatically tested to failure at both room temperature and at −50° F.

Subsequent vessels were cycled from near zero to maximum pressure at stress levels above the yield point. Simulated nozzles were inserted into the shell, and machined notches of varying severity were machined in the cylindrical walls of the vessels.

A final series of tests was conducted in which the membrane strain level was near the upper limits of the elastic range, but with local concentrations far into the plastic range because of discontinuities, in the form of intentional stress raisers of various types. Failure was defined as the propagation of a crack to the point of actual leakage.[8, 9, 10]

Evaluation of the Three Testing Methods

The three testing methods are obviously different as far as strain application and loading are concerned, and, therefore, should not be expected to yield numerically identical results. Their different features, however, make each of them suitable for furnishing information on specific phases of pressure vessel design. It is, therefore, well to evaluate these features and establish their field of usefulness so that the data

derived from them can be applied to the problem in the most pertinent manner.

The cylindrical shell of a pressure vessel is relatively free of points of stress concentration and is thus generally resistant to fatigue. The cyclic life of a pressure vessel depends primarily on the ability of the material to sustain repetitive inelastic straining in the boundary and junction regions subject to strain concentration during major pressure cycles. The ability of a steel for pressure vessel service to withstand this repetitive deformation is, therefore, best determined by a specimen in which the material can be subjected to a known strain during the cycle and from which all other disturbing influences can be eliminated as much as possible. The Lehigh specimen fulfills these requirements in a practical manner. The machined and ground surface in the test region of the specimen allows measurement of the average applied strain and, within practical limits, avoids disturbing influences such as surface imperfections or other mechanical or metallurgical discontinuities. It provides a means of measuring the ability of the material to sustain repeated plastic action as a characteristic of the material itself.

In many of the localized boundary and junction regions of a pressure vessel the configuration of the surface does not lend itself to exact measurement of the strain. Also the effect of small notches, surface defects and metallurgical variations, such as exist in and around welds, cannot be measured directly. Additional testing methods are, therefore, necessary to measure these effects by establishing their fixed relationship to a strain that can be measured. Both the Illinois and the École Polytechnique specimens are designed to furnish this kind of data. The model vessels, however, should not be used beyond the point where measured membrane strains surpass the yield point. The reason for this limitation is inherent in the purpose of the tests.

Since the primary purpose of these tests is to furnish the designer with specific data that will predict the cyclic life of various configurations of geometry in the pressure vessel structure, the loading and the strain relationship between the membrane areas and the localized regions must be the same as in actual practice. In practice it is generally not safe to subject a pressure vessel to a test so severe that the membrane areas are stressed beyond the yield point. Since the strain in the relatively small strain concentration regions is principally dictated by the large membrane areas surrounding them, there will exist a fixed relationship between the two for the life of the vessel. (For severe strain in small volumes of metal this will not be strictly true, but it has been shown on the Lehigh and Illinois specimens that the strain range and the hysteresis level off to a constant value after approximately 10 cycles.) In order to obtain pertinent data, this fixed relationship must also be retained during the cycling life of the specimen, and this can only be approached to an acceptable degree if the membrane areas are not strained beyond the yield point. This reasoning can best be illustrated by observations made on the Illinois flat-plate tests.

At the higher pressures that were required to produce failure of the unnotched plate in a small number of cycles, the plate specimen is bulged upward permanently. The resulting amount of cold work changes the physical characteristic of large portions of material of the specimen and radically changes the proportionality between the dominating membrane areas and the critical test area, which in this case was the central region of the top surface of the plate. After this initial deformation, the testing conditions are not coordinated any longer with the known starting conditions, as far as strain distribution and physical properties are concerned, nor do they simulate the strain relationships in the membrane of a vessel in actual service. Since proportionality has been destroyed, testing such a specimen degenerates to the same "no-man's-land" as that obscure region covered by the factor of safety in the hydraulic destruction test. The rather spectacular performance of the A201 Grade A unnotched flat plates (Fig. 16, Reference 5) is in this category and must, therefore, be discounted.

The same type of specimen containing a notch does not show this marked superiority at the lower life cycles. The nominal strains in the surface of the plate of the notched specimen did not exceed the yield point and notch strain ratios were not "blunted" by general distortion. This test condition more nearly simulates a pressure vessel service condition.

The vessel model used at École Polytechnique is particularly subject to difficulties of interpretation when the membrane areas are strained beyond the yield point. Although the Illinois and the École Polytechnique specimens serve the same general purpose, the Illinois specimen has been most useful in evaluating general plate surface conditions and the effects of welding and the presence of relatively small machined notches. The École Polytechnique specimen can also accommodate larger structural components or attachments.

Interpretation of Fatigue Data

In order to define the influence of plastic fatigue on pressure-vessel design the data must provide information in three major areas:

1. The ability of the material of construction to sustain many cycles of plastic strain must be measured as a characteristic of the material itself. As a matter of convenience, this characteristic can be called "Plastic Endurance."

2. A relationship must be established between an allowable strain on the large membrane areas and the plastic strain in the discontinuities of boundary and junction regions. This relationship can be called the strain concentration factor f_e of a configuration.

3. The relative merit of various design conditions and configurations must be determined either by computation or by testing representative specimens. By determining the strain concentration factor of discontinuities in the structure, such as surface defects, welding, notches, fillets, knuckles, openings, etc., the designer will be able to avoid "weak spots" in his design, and the inspector will be aware of the conditions that lead to premature failure and which should be corrected.

The data obtained in the over-all program will, therefore, be evaluated along these conceptual requirements.

General

In Table 1, the chemical analyses and tension test data are given for all of the steels, including those which were prestrained or heat treated to vary their yield and tensile properties. Table 2 constitutes a compilation of all fatigue data collected at the three laboratories. In the case of the tests at Illinois and Lehigh, the fatigue resistance of the steels is expressed as the allowable strain range which will cause failure in a stated number of cycles. Strains are given for several cycle levels, such as 5000, 20,000 and 100,000 cycles. It has been found that in shorter ranges of life cycles the plastic fatigue strength for a given life depends more upon the magnitude of the cyclic strain than it does upon static mechanical strength. A much broader range in cycles could have been covered to advantage, but the range from 5000 to 100,000 has fortunately revealed this concept sufficiently to indicate that additional work is necessary only for confirmation.

In the limited number of model tests at École Polytechnique, it was possible to study only the effect of two steel compositions and a variety of fabrication details introduced into the vessels.

The data, therefore, are expressed as the cycles at which failure occurred at various locations in the vessels for two or three pressure ranges.

Plastic Endurance

Plastic endurance as a characteristic of a material can be determined only on a machined specimen of a specified surface finish on which the strain can be measured directly. The data obtained on the Lehigh specimen serve this purpose and they have, therefore, been plotted in Fig. 2, showing strain range e versus cycles to failure N. This type of plot in plastic fatigue corresponds to the finite portion of the SN diagram in conventional fatigue.

A study of this plot reveals an important change in the relationship between allowable strain range and the tensile characteristics of the steel at various endurance levels.

In conventional fatigue it has been generally established that the endurance limit is proportional to the tensile strength. In plastic fatigue, at a life of 100,000 cycles, this still appears to be true in a broad sense. At a life of 20,000 cycles, this statement is not reliable any longer, and at a life of 5000 cycles, the influence of mechanical strength has disappeared. Only the magnitude of the strain range, and not the static strength characteristics of the material, determines the strength for the low numbers (say $<10^4$) of cycles to failure. A limited number of tests conducted at Lehigh[2] indicate that at very low numbers of life cycles the criterion for endurance approaches the ductility of the material as measured in the conventional tensile test.

Within a relatively narrow scatter band, the plastic endurance at this lower number of life cycles is about the same for all steels. This phenomenon can be expressed in a manner more useful to the designer by saying that, for a relatively low number of expected service cycles (approximately 10,000 and below*), only the maximum strain range governs the safety of the vessel. In applications where the cyclic strain and repetitive loading are in this lower number of expected service cycles, large strains can be tolerated and poorly designed vessels having design components with high strain concentration factors can still give long time service. For this class of design there is no advantage in specifying high-strength steel. The conventional lower strength steels would serve equally well or better. For good design having low strain concentration factors, a high-strength steel would probably be advantageous since it would sustain greater cyclic pressure variations to develop the same strain range. When the high cyclic strains are caused by large temperature gradients rather than pressure loading, the emphasis is again more on the high plasticity characteristics than the high strength of the material.

Over the range of plastic endurance investigated, a definite change in parameters seems to take place. Whereas,

Table 1

Tensile properties of the high strength steels

Steel	*Condition*	*Yield strength, 0.2% offset, psi*	*Tensile strength, psi*	*Reduction in area, %*	*Elongation, (2 in.), %*	*Bhn*
2-A201	N & SR	36,400	59,000	68.5	39.5	132
3-A302	N & SR	65,800	87,000	64.2	26.2	204
4-A201	N & SR	36,500	57,800	69.6	39.0	131
4-A201	A	34,000	55,100	67.0	37.5	116
4-A201	N	38,600	60,600	68.2	35.5	121
6-A302	N & SR	58,300	78,500	66.5	29.2	158
6-A302	QT 1300	74,000	92,500	72.0	27.5	188
6-A302	QT 400	159,500	195,500	52.0	14.0	322
6-A302	A	49,800	73,100	61.6	31.8	153
6-A302	10% PS	89,500	89,500	63.2	17.5	...
A225	N & SR	52,500	76,100	65.0	29.2	134
Fortiweld	N & SR	64,500	82,200	65.1	20.5	172
T-1	Mill QT	123,400	130,000	50.2	15.5	272
T-1	A	80,100	115,500	52.4	17.2	241
48s5	Mill N	48,400	70,600	70.0	31.7	144
48s5	A	45,800	66,500	66.2	33.3	131
48s5	QT 1275	71,700	84,900	74.4	28.8	184
48s5	15% PS	82,500	83,500	53.1	20.5	177
B-A302	Mill N	52,300	87,300	58.3	24.4	196
B-A302	SR	62,300	81,800	61.8	26.2	181
NES70	SR	84,800	101,800	56.2	19.5	222
NES70	A	61,000	84,600	57.9	26.2	178
NES70	QT 1200	98,700	107,500	65.0	21.9	237
NES70	8% PS	111,600	111,600	38.6	13.8	241
NavyG	Mill NT	79,200	95,200	71.0	25.5	230
J-Alloy	Mill QT	113,000	129,500	61.5	17.5	279
1045	A	45,000	87,300	46.0	25.0	168
1045	N	57,000	97,200	51.3	24.5	188
1060	A	42,800	90,000	41.4	25.8	177
1060	N	57,200	102,000	45.7	23.2	210
1080	A	45,000	102,600	24.5	15.0	200
1080	N	56,400	126,800	24.9	14.8	243

* Lower life cycle ranges have been investigated by A. C. Low.[13]

Chemical analyses of the steels tested

Steel	*C*	*Mn*	*P*	*S*	*Si*	*Ni*	*Cr*	*Mo*	*V*	*Ti*	*Cu*	*B*
2-A201*	0.14	0.38	0.017	0.034	0.20	...	...	...	...	...	...	...
4-A201	0.13	0.40	0.013	0.029	0.20	...	...	...	...	...	...	...
3-A302*	0.18	1.44	0.024	0.033	0.27	...	...	0.48	...	...	...	...
6-A302	0.17	1.18	0.017	0.025	0.25	...	...	0.43	...	...	...	...
B-A302	0.21	1.31	0.022	0.027	0.24	...	...	0.41	...	...	...	...
A225	0.20	1.28	0.023	0.035	0.15	...	...	...	0.09	...	...	...
Fortiweld	0.13	0.49	0.023	0.042	0.24	...	...	0.48	...	...	...	0.003
T-1	0.16	0.93	0.014	0.023	0.26	0.87	0.50	0.45	0.06	...	...	0.003
48s5	0.15	1.12	0.034	0.031	0.18	0.06	0.05	0.02	0.09	0.007	0.11	...
NES70	0.21	0.75	0.017	0.033	0.03	2.04	0.04	0.22	...	...	0.95	...
Navy G	0.13	0.48	0.013	0.029	0.21	2.17	0.06	0.39	0.11	...	0.73	...
J-Alloy	0.31	1.45	0.014	0.017	0.25	0.07	0.03	0.12	...	...	...	...
1045	...	...	...	...	...	...	...	...	...	...	...	...
1060	0.58	0.73	0.014	0.032	...	...	...	...	...	...	...	...
1080	0.84	0.81	0.015	0.031	...	...	...	...	...	...	...	...

N—normalized; SR—stress relieved; A—annealed; Q—quenched; T—tempered; PS—prestrained.
* These heats of A201 and A302 were tested at Illinois, École Polytechnique and Lehigh.
Note: Numbers and letters preceding A201 and A302 designate different heats

at the lower life cycles, only the magnitude of the strain range governs the number of cycles to failure, at the higher endurance levels of 20,000 to 100,000 and above, the allowable strain range shows an increasing dependence on tensile properties. It was, therefore, of interest to explore this relationship in further detail.

Correlation of Fatigue Data with Tensile Properties

An extensive analysis was performed to learn what relation exists between plastic fatigue resistance and the properties measured by the tensile test on a 0.505-in. standard specimen. Of the many comparisons made, a few were sufficiently good to be of interest.

Table 2—Summary of Fatigue Data Obtained at Lehigh Illinois and École Polytechnique

Lehigh University data

		Unnotched			*Notched*			*Welded*	
Steel	*Condition*	*Strain range at 5000 cycles*	*Strain range at 20,000 cycles*	*Strain range at 100,000 cycles*	*Strain range at 5000 cycles*	*Strain range at 20,000 cycles*	*Strain range at 50,000 cycles*	*Strain range at 5000 cycles*	*Strain range at 100,000 cycles*
2-A201	N & SR	1.25	0.57	0.34	...	0.43	0.32	...	...
3-A302	N & SR	1.04	0.72	0.47	0.90	0.59	0.45	1.01	0.44
4-A201	N & SR	1.50	0.67	0.34	...	...	...	1.22	0.35
4-A201	A	1.27	0.57	0.35	...	...	...	...	...
4-A201	N	1.36	0.77	0.40	...	...	...	...	...
6-A302	N & SR	1.14	0.67	0.44	...	...	...	1.14	...
6-A302	QT 1300	1.08	0.56	...	...	...	...	...	...
6-A302	QT 400	...	0.89	0.60	...	...	...	...	...
6-A302	A	1.17	0.60	...	...	...	...	...	...
6-A302	10% PS	1.12	0.66	0.47	...	...	...	...	...
A225	N & SR	1.27	0.68	0.37	0.98	0.46	...	1.10	0.39
Fortiweld	N & SR	0.94	0.67	0.46	0.89	0.59	0.45	0.99	0.48
T1	Mill QT	1.09	0.82	0.61	1.01	0.74	0.60	1.09	0.62
T1	A	0.99	0.71	0.54	...	...	...	...	...
48s5	N	1.25	0.65	0.41	1.01	0.54	0.36	1.15	0.41
48s5	A	1.35	...	0.38	...	...	...	...	...
48s5	QT 1275	1.05	...	0.49	...	...	...	...	...
48s5	15% PS	0.95	...	0.49	...	...	...	...	...
B-A302	N	1.12	0.79	0.53	1.00	0.64	0.52	1.06	0.49
B-A302	SR	...	...	0.51	...	...	...	...	...
NES70	SR	1.10	0.74	0.56	0.92	0.62	0.48	1.02	0.60
NES70	A	1.25	...	0.57	...	...	...	...	...
NES70	QT 1200	1.10	...	0.62	...	...	...	...	...
NES70	8% PS	1.17	...	0.63	...	...	...	...	...
Navy G	Mill NT	1.27	0.81	0.56	0.94	0.66	0.52	1.09	0.54
J-Alloy	Mill QT	1.12	0.78	0.56	0.99	0.69	0.58	1.09	0.54
1045	A	1.45	0.85	0.46	...	...	...	...	...
1045	N	1.52	0.88	0.46	...	...	...	...	...
1060	A	1.44	0.88	0.50	...	...	...	...	...
1060	N	1.55	0.94	0.52	...	...	...	...	...
1080	A	1.28	0.82	0.52	...	...	...	...	...
1080	N	1.40	0.91	0.57	...	...	...	...	...

University of Illinois data

		Unnotched		*Notched*		*Welded*	
Steel	*Condition*	*Strain range at 20,000 cycles*	*Strain range at 100,000 cycles*	*Strain range at 20,000 cycles*	*Strain range at 100,000 cycles*	*Strain range at 20,000 cycles*	*Strain range at 100,000 cycles*
2-A201	N & SR	...	0.18	0.16	0.13	...	0.18
3-A302	N & SR	0.31	0.21	0.22	0.17	0.35	0.26
A225	N & SR	0.30	0.20	0.16	0.13	...	...
48s5	N	0.40	0.24	0.20	0.16	0.34	0.24
Navy G	N & T	0.36	0.25	0.26	0.19	0.37	0.27
NES70	T	0.40	0.27	0.24	0.17	0.37	0.28
J-Alloy	Q & T	0.44	0.30	0.24	0.18	0.45	0.33
T-1	Q & T	0.40	0.27	0.22	0.16	0.42	0.32

École Polytechnique data

			Dynamic strain range	*No. of cycles to failure*		*No. of cycles to failure*			
Vessel	*Steel*	*Stress*		*Square-edge nozzles*	*Rounded-edge nozzles*	*Charpy V notch*	*1/8-in. radius notch*	*3/8-in. diam hole, 7/16 in. deep*	*Weld seam*
G	2-A201	5% above yield	0.074	51,000	...	No failure	...	...	No failure
H	2-A201	5% below yield	0.066	90,000	>271,000	No failure	No failure	No failure	No failure
M	3-A302	5% below yield	0.122	19,000	>36,000	42,000	63,000	No failure	39,000
P	3-A302	17.5% below yield	0.105	...	50,000	49,000*	No failure	No failure	No failure
L	3-A302	13% above yield	0.145	10,000	...	No failure	...	...	No failure

* Beginning of crack.

N—normalized; SR—stress relieved; A—annealed; Q—quenched; T—tempered; PS—prestrained.

Note: Numbers and letters preceding A201 and A302 designate different heats.

These are shown in the accompanying figures.

Figure 3 shows the relation between tensile strength and fatigue resistance at 100,000 cycles. Both Illinois and Lehigh data are included in the figure. The Illinois fatigue data are about one-half the magnitude of the Lehigh results. This discrepancy arises from several sources: (1) failure in the Illinois specimens was taken as the point at which a $^3/_{16}$-in. crack became visible, while the end point of the Lehigh tests was complete fracture of the test section, (2) the Illinois specimens contained the irregularities of the original plate surface, whereas the Lehigh specimens were ground to a 50-grit finish, (3) post-test calibration of the optical strain gages used for the Lehigh tests revealed the necessity for a correction factor to lower their strain readings 15%.

Good proportionality between allowable strain and tensile strength is shown for the machined (Lehigh) specimens at the lower strains. At the larger strains, proportionality declines and scatter increases. For the Illinois tests the data do not show proportionality even at the lower strains and scatter is about constant over the range. The main reason for this is that the "as-rolled" plate surface contains imperfections in which the local strains are much larger than on the surface of the machined specimens. Since these local strains are above the elastic range, they govern the shape of the curve and the scatter. However, only the nominal strain as measured by strain gages on the plate surface is used in the plot. These, therefore, show this change at a lower level on the plot. Since, in fatigue investigations of small polished specimens, it has been established that the endurance limit of most steels is proportional to tensile strength, it appeared logical to see if this relation would still hold at 100,000-cycle life. For this purpose, a literature survey was conducted to review the available data on the relation between tensile and fatigue strength of a considerable number of investigations in which a variety of unnotched test specimens were used. By selecting data derived from simple machined and polished specimens only, the uncontrolled variables mentioned above were avoided as much as possible. The principal variables in these data, by virtue of the selective process, were therefore the tensile and the fatigue characteristics of the materials. Figure 4 summarizes the relation between the tensile and the fatigue data on these investigations. Although they covered a variety of testing methods and metals, there is remarkably good correlation. For comparison, the corrected curve for the Lehigh data and the one for the Illinois data are replotted on Fig. 4. At the higher strains the deviations from the curve are large enough to affect the ranking of the various steels tested. This plot, therefore, gives only an approximate relationship. The plastic endurance can more accurately be determined by conducting sufficient tests to construct an ϵN diagram.

Since fatigue is most sensitive to the surface conditions of the specimen, a plot was made in Fig. 5 of the surface Brinell hardness against fatigue performance for Lehigh data. In general, the plot was improved by this step. It is possible that other surface conditions, such as decarburization, which lower strength locally could also produce a corresponding loss in fatigue resistance.

In Fig. 6 the relation between yield strength and allowable strain at 100,000 cycle life is shown for the Lehigh tests. The widely divergent scatter band and the rapid loss of proportionality indicate that, at the higher strain levels, yield strength affects the allowable strain only to a minor degree and cannot be used as a parameter for plastic en-

TYPE	CONDITION	YP	TS
A-201-A	N&SR	36000	59000
48s5	N	48400	70600
A-302-B	N&SR	65800	87000
NAVY G	MILL N&T	79200	95200
NES 70	SR	84800	101000
J ALLOY	MILL Q&T	113000	129000
T-1	MILL Q&T	123000	130000

N-normalized; SR-stress relieved; Q-quenched; T-tempered

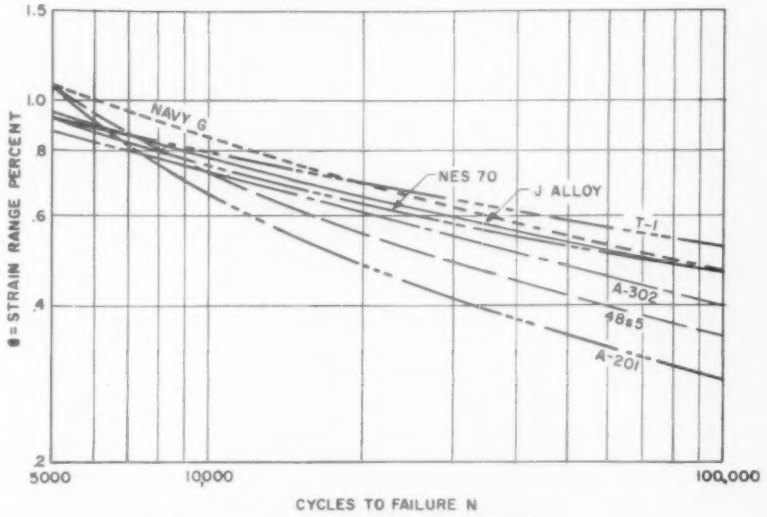


Fig. 2 Plastic endurance of several pressure-vessel steels

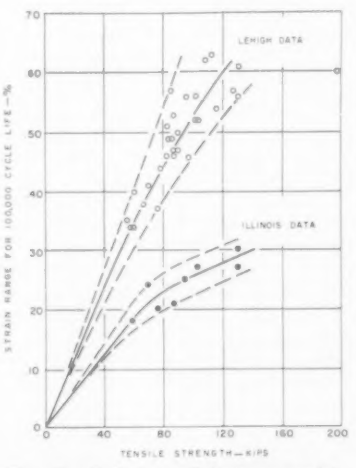


Fig. 3 Relation of fatigue resistance to tensile strength in the Lehigh University and University of Illinois tests on unnotched specimens

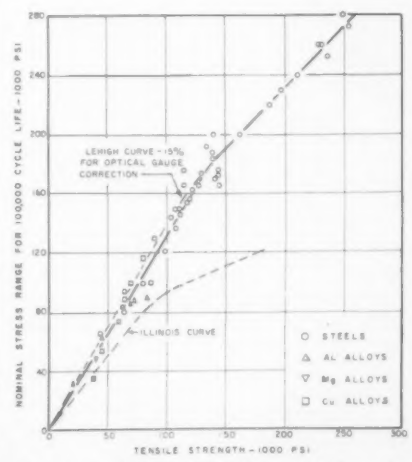


Fig. 4 Relation of fatigue resistance to tensile strength for a variety of materials

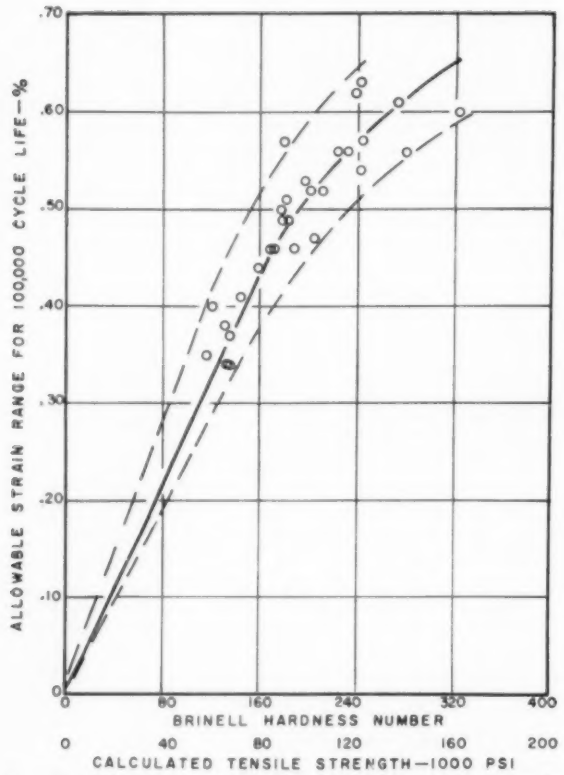


Fig. 5 Relation of fatigue resistance to surface tensile strength as determined from Brinell hardness

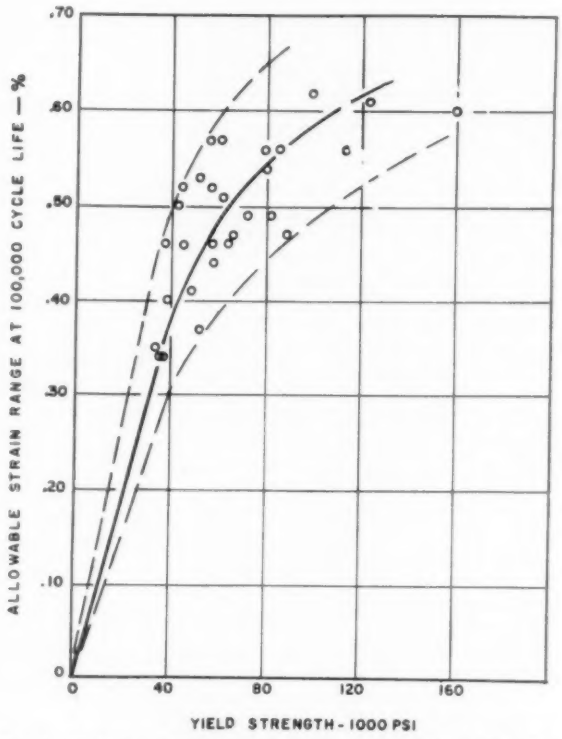


Fig. 6 Relation of fatigue resistance to yield strength in the Lehigh University tests

durance.

Another summary of the trends observed at 100,000 cycles in the Illinois tests is shown in Fig. 13, Reference 7. These data show that the plastic fatigue strength of unnotched and notched plate is a diminishing portion of the static strength for the higher strength steels. Here again the drop in ratio of plastic fatigue strength to yield strength is much more pronounced than the ratio to tensile strength.

In the recent paper by Murphy, Soderberg and Rossheim[11] it was suggested that fatigue performance might be indexed to the factor, $\frac{1}{2}$ (yield strength + tensile strength) × % elongation. Although this expression can be looked upon as a measure of available plastic deformation energy, it does not show any relationship to plastic fatigue performance as demonstrated in Fig. 7.

In addition to the graphs which have been presented here, a large number of correlations were attempted with other parameters of the tension test, with no useful result. These included true stress, true strain, strain-hardening exponent, uniform elongation and various combinations of tensile strength, yield strength and tensile ductility.

Effect of Temperature

The effect of temperature on fatigue strength from 0 to 650° F is summarized in Table 3. No loss in fatigue properties was evident over this range of temperatures. The improvement experienced at elevated temperatures is not readily explained, unless it is due to strain aging produced by the plastic cycling which raises the tensile strength.

Effect of Cycling Speed

It has been reported that the rate of cycling influences fatigue resistance (see Reference 15, p. 583). The test results listed in Table 4 confirm this. A change in cycling rate from 12,000 to 7 cycles per hour reduced the life about 15%. It should be noted that, because of the relation between allowable strain and cycles to failure, a 15% reduction in life corresponds to an 8–10% reduction in allowable strain. In a great number of vessels, the service requirements call for long periods between major strain cycles. The slow cycling rate on such vessels, however, does not call for a reduction in allowable strain

Table 3—Effect of Testing Temperature on Plastic Fatigue Resistance

	4-A201		*3-A302*	
Temp, ° F	*Strain range at 5000 cycles*	*Strain range at 100,000 cycles*	*Strain range at 5000 cycles*	*Strain range at 100,000 cycles*
0	...	...	1.00	0.48
75	1.50	0.34	1.04	0.47
650	1.65	0.43	1.40	0.62

Table 4—Effect of Cycling Rate on Plastic Fatigue Life

(cycles to failure at indicated strain range)

A201 steel normalized and stress relieved

Testing speed, cycles/hr.	*1% strain range*	*2% strain range*
12,000	11,000	2400
75	9,500	2100
7	...	1650

A302 steel normalized and stress relieved

Testing speed, cycles/hr	*0.65% strain range*	*0.9% strain range*	*1.5% strain range*
12,000	23,000	9500	2700
75	15,000	8500	2150
7	...	...	2300

range because for vessels with a long service cycle, the total number of major cycles is generally far below 100,000 cycles. The greater strain range allowable for the smaller number of total cycles more than compensates for the reduction resulting from the slow cycle (Table 1).

Determination of Strain Concentration Factor

In the section on the evaluation of testing methods, it was pointed out that valid data could be obtained from the model vessel specimens only if the membrane stress were kept below the yield point. It was shown that this was necessary to maintain a constant ratio between the elastic strains in the large membrane areas and the plastic strains in the much smaller notches and the boundary and junction regions. By maintaining this constant ratio, the strain concentration factor of the latter configuration can be determined. By definition, the strain concentration factor is the ratio between the measured strain on a machined specimen and the effective strain in a notch or discontinuity for the same cycling life for a given geometry and material.

The measured strain versus number of cycles to failure reflects the ability of a steel to withstand repetitive plastic strain, and is given for a representative group of the steels in the eN diagram as shown in Fig. 2. The method of determining the strain concentration factor will, for the sake of simplicity, be shown only on one material which has been tested in all three laboratories, namely, A201 Grade A. The plastic endurance of this material has, therefore, been replotted in the eN diagram shown in Fig. 8. The lower curve relates strain range to the cycles required to form a crack $^3/_{16}$ in. long. The upper curve relates strain range to the cycles at fracture of the Lehigh specimen. The Lehigh data are corrected 15% downward in strain values as dictated by the optical strain gage calibration.

To determine the strain concentration factor of a notch or configuration that cannot be measured directly, a specimen containing such a discontinuity is subjected to a cycling test while the nominal strain e_1 near the discontinuity is measured with a strain gage. When the specimen fails, the number of cycles to failure is noted = N_1. The actual strain e_0 at which this material fails in N_1 cycles in accordance with its plastic endurance characteristic can then be determined from Fig. 8. The strain concentration factor (f_e) of the discontinuity is then e_0 divided by e_1.

The effective strain-raising factor can be defined as follows: f_e = strain range on ground Lehigh specimen/measured nominal strain range on specimen under test = e_0/e_1 for equal cycling life.

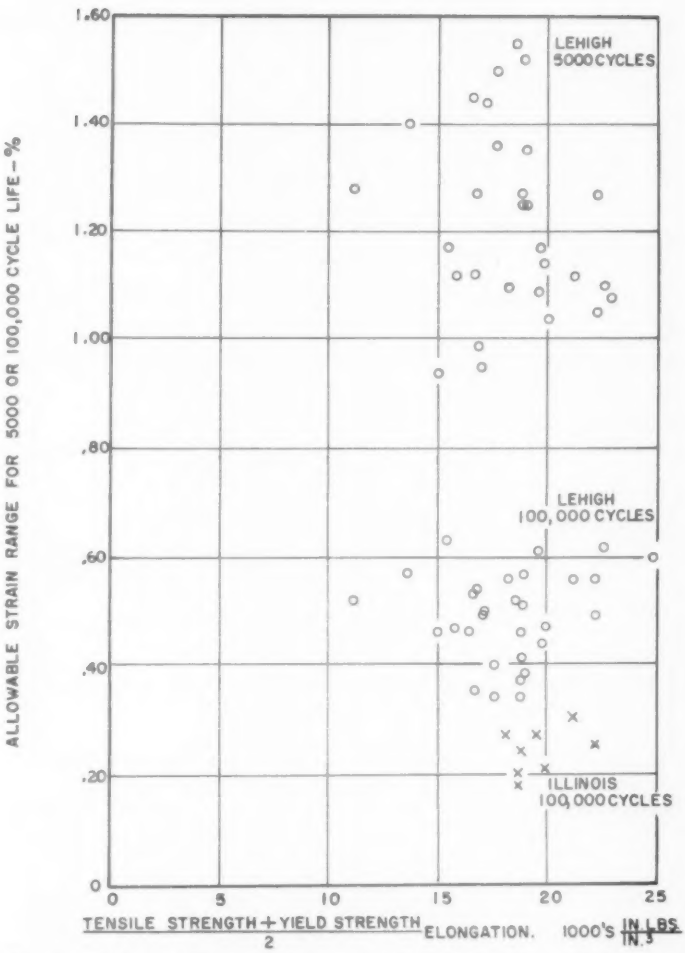


Fig. 7 Plot of fatigue resistance vs. fatigue-life index proposed by Murphy, Soderberg and Rossheim[11]

Example 1: Strain-Raising Factor for Illinois Notched Plate. From Fig. 8, the A201 steel can be expected to form a $^3/_{16}$-in. crack after 70,000 cycles at a strain range of 0.285%. In the Illinois tests, notched A201 plate failed after 70,000 cycles at a nominal measured strain range of 0.13%. Thus, the notch strain-raising factor for the notched plate is simply 0.29/0.13 = 2.3.

Example 2: Strain-Raising Factor for Sharp Nozzle in Model Vessel. The sharp nozzles failed in the A201 steel vessel at 90,000 cycles for a pressure 5% below the yield point, also measured dynamically as a strain range of 0.066%. From Fig. 8, the Lehigh data for failure indicate an allowable strain range for 90,000 cycles of 0.30%. Thus, the factor for the sharp nozzle is 0.30/0.066 = 4.6.

By means of the procedures outlined above, Table 5 was prepared to show the strain-raising characteristics of plate surfaces, notches and attachments. These are useful because they give some idea of the limitation that will be imposed on the fatigue resistance of pressure vessel steels by inadvertent strain raisers.

Application of Fatigue Data

From the results in Table 5, with particular reference to the model-vessel tests, it appears that the most severe and unavoidable discontinuity tested in a pressure vessel is the nozzle attachment. This discontinuity has an effective strain-raising factor f_e of about 4, if we ignore the sharp-cornered nozzles which are not an accepted construction.

Judging from experimental stress analysis of full-size vessels,[14] this factor appears unnecessarily high and may, at least in part, be due to the small size of the model vessels. For a carefully designed vessel in which intersections of surfaces are more thoroughly "streamlined" the governing strain concentration factor should be kept well below this value. To what extent the aggregate strain-raising factor of surface condition plus geometry can be reduced,

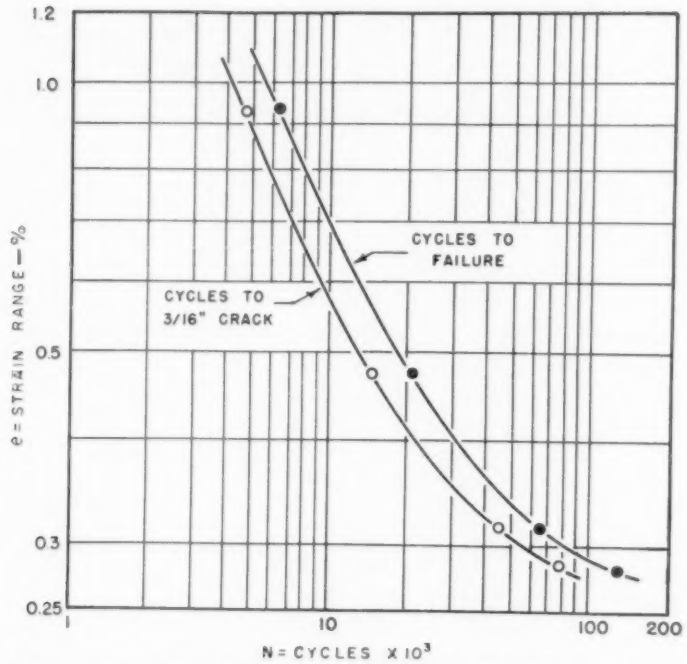


Fig. 8 Plastic fatigue behavior of A201 in the Lehigh test; normalized and stress relieved; 50 grit ground finish

will have to be determined experimentally on vessels of considerable size. The model vessel and nozzle attachment used at École Polytechnique are too small to translate with confidence to full-size performance.

As an illustration of how these data can be used for actual design information, Table 6 was compiled to show the limiting membrane stresses that can be present in a vessel constructed of each of the high-strength steels tested in the PVRC investigations. The limiting membrane stress is here computed as a function of the allowable strain range for a 100,000-cycle life. As a matter of comparison, the limiting membrane stress is also given as a percentage both of tensile strength and the yield strength. These values again show that stresses based on plastic endurance are proportionately lower for the high-strength steels and that they are least responsive to an increase in yield strength.

Thus, in a vessel assumed to have fairly high strain raisers present, the membrane stresses can be of the order of one-third the tensile strength of the steel and still not expose the vessel to fatigue failures for a life of 100,000 cycles.

These are limiting values and do not contain a safety factor beyond that provided by the high strain concentration factor assumed. Such a factor has to be imposed by the code-making bodies. It can be introduced in two ways: by limiting the number of major cycles N or by limiting strain e. Such safety factors can be made realistic by basing them on limiting values established by full-scale tests. The number of cycles is generally determined by the service requirements; the strain e can be kept to a minimum by good design.

Application to Design

In designing a vessel subject to repeated loading or other cyclic strain conditions, the most severe strain concentration factor has to be determined by experiment. (The values given in this paper can be used tentatively, but they should be checked and extended by further work on configurations and materials pertinent to each case.) The number of cycles expected during the service life of the vessel must be estimated. From these two sets of values and the plastic endurance of the material as given in its eN diagram, the limiting performance of the structure can be determined. By applying the safety factor(s), to be determined by code, the allowable membrane stresses are defined. When the estimated number of cycles of maximum strain is below 10,000, plastic fatigue considerations do not dictate the choice of material. Only in very poor design with extremely high strain concentration factors could the large strains allowable even be approached as a result of pressure loading. There is, however, the possibility in some applications in which severe thermal strain can be superimposed on high "pressure strain," that plastic fatigue failure may again become the controlling factor in the safety of the vessel. These superimposed thermal strains are independent of the static strength characteristics of the steel and can be sustained equally well by a lower strength steel with good plastic endurance as by a high strength steel. In such applications, consideration of strains due to pressure loading will in most cases lead to the choice of a high-strength steel, but the allowable thermal strain is determined by the margin remaining within the limits for total allowable strain derived from plastic endurance considerations.

Obviously, the designer's greatest opportunity to increase the allowable membrane stresses is by keeping the strain concentration factor of the various boundary and junction regions as low as possible.

Application to Inspection

Although the designer can embody the proper design in drawings and specifications, it is the final inspection that will assure that it enters service in the proper condition.

In order to make an intelligent inspection, the inspector must have a correct evaluation of the relative potential of the various irregularities to cause failure. From the correlation of the results at the various laboratories on the magnitude of the strain concentration factors of plate surface defects, various notches, and nozzles, as given in Table 5, a set of representative values can be extracted as shown below:

Rolled plate surface	$f_e = 1.6$
0.01-in.-deep notches	$f_e = 2.7$
0.06-in.-deep notches	$f_e = 3.8$
Rounded nozzles	$f_e = 4.0$
Sharp-radius nozzles	$f_e = 4.7$

The individual values shown in Table 5 show some scatter from the average; they are, however, sufficiently consistent to help the inspector in judging the condition of a vessel during a final inspection. It is evident that a vessel need not be polished all over to be safe for service, but it is equally apparent that one should look with particular care for notches and cracks in areas that are already subject to high strain on account of their own geometry.

Plastic Endurance vs. Material Characteristics

Results at the University of Illinois (see Figs. 5 and 6, Reference 13) on high-tensile strength materials, as well as the very limited data from the model-vessel tests, appear to indicate that the strain concentration factor is not a function of geometry alone, but is also dependent on material characteristics. The effect of material characteristics has to be further investigated to determine to what extent they are a controlling factor. It is quite possible that the relative volume of metal involved in plastic action at each strain raiser, after the stress-strain hysteresis has

been stabilized in the first few cycles, is a factor. This relative volume in turn can depend on a variety of factors, such as yield-to-tensile-strength ratio, strain hardening, amount of general strain, shape of the stress-strain curve, Bauschinger effect, etc. Although the aggregate effect does not appear to be a strong variable, it may be of sufficient significance to affect the ranking of some of the steels. A blanket value of f_e = 4 for the most severe discontinuity, as used in the Table 6, therefore must be regarded as tentative and probably conservative at the present stage of knowledge. For critical cases, it is not advisable to generalize, and specific information on the plastic endurance (ϵN diagram) of the material *in its final condition* should be obtained along with other tensile data.

With the background developed and the actual data now available, it may be possible to devise a simple and practical test to measure this aggregate effect. It is not unreasonable to expect that a Lehigh-type specimen with a central hole instead of a throated section might bring out the effect of such material characteristics. The largest possible size specimen that can economically be justified should be employed. Transient thermal strains are generally superimposed on those caused by pressure loading. They are of maximum magnitude at the surface of the plate and are usually of an equibiaxial nature. They could best be simulated by a circular flat plate specimen held in a pressure-tight frame in such manner that it could be loaded hydraulically on each of its two sides alternately. This type of specimen could also serve to investigate the effect of materials on plastic notch sensitivity.

Summary

The following conclusions can be drawn from the PVRC investigations of plastic-fatigue properties of pressure-vessel steels. They are grouped under three categories: (1) influence of material, (2) influence of geometry and (3) influence of cycling conditions.

A. *Material Factors*

1. For a limited number of tests conducted in the range between the simple tensile test and approximately 5000 life cycles, the maximum strain correlates best with the ductility of steel as represented by the elongation measured in the conventional tensile test.

2. For an intermediate number of cycles to failure, from about 5000 to 20,000, the cyclic plastic strains in the steels investigated were nearly independent of the tensile characteristics of the material. Only the magnitude of the strain governs the life of the specimen. The corresponding pressures allowable in vessels made of these steels would, however, vary with the allowable membrane stress.

3. At the level of 20,000 to 100,000 cycle life and above, the resistance to plastic fatigue is more closely proportional to tensile strength. The influence of composition, microstructure and mechanical history of the plates on fatigue is parallel to their influence on tensile strength. This correlation is true for relatively small strains. At the higher strains, the most pertinent criterion for the plastic endurance of a pressure vessel steel is the ϵN diagram obtained from a series of tests in which the maximum strain range is measured directly.

Table 5

Calculation of strain-raising factors in fatigue tests

	Illinois rolled and pickled plate surfaces			*Illinois V-notched plates**	
Steel	*Strain for 3/16-in. crack in Lehigh specimen, 20,000 cycles, %*	*Strain for 3/16-in. crack in Illinois specimen, 20,000 cycles, %*	*Strain-raising factor*	*Strain for 3/16-in. crack in Illinois notched specimen, 20,000 cycles, %*	*Strain-raising factor*
A201	0.30†	0.21†	1.43	0.13†	2.3
A225	0.48	0.29	1.65	0.16	3.0
48s5	0.56	0.38	1.48	0.20	2.8
A302	0.57	0.32	1.78	0.22	2.6
NES70	0.59	0.40	1.47	0.24	2.5
Navy G	0.64	0.36	1.78	0.26	2.5
J-Alloy-3	0.63	0.44	1.43	0.24	2.6
T-1	0.66	0.40	1.65	0.22	3.0
		Avg value of factor	1.6	Avg value of factor	2.7

École Polytechnique model vessels

Sharp nozzles:‡

Vessel	*Steel*	*Cycles to failure*	*Strain range, %*	*Lehigh strain range for same cycles*	*Strain-raising factor*
G	A201	51,000	0.074	0.34	4.6
H	A201	90,000	0.066	0.30	4.6
L	A302	10,000	0.145	0.73	5.0
M	A302	19,000	0.122	0.60	4.9
				Avg value of factor	4.7

Other vessel details:

Vessel detail	*Cycles to failure*	*Strain range, %*	*Lehigh strain range for same cycles*	*Strain-raising factor*
G(A201) V notch§	>159,000	0.074	0.28	<3.8
M(A302) V notch	42,000	0.122	0.47	3.8
P(A302) V notch	>57,000	0.105	0.44	<4.2
P(A302) rounded nozzle‡	50,000	0.105	0.46	4.4**
M(A302) rounded nozzle	>37,000	0.122	0.49	<4.0
H(A201) rounded nozzle	>270,000	0.066	0.27	<3.9

* For detail of notch see Fig. 2, Reference 5.
† Values for 70,000-cycle life.
‡ For detail of nozzle, see Fig. 2*b*, Reference 10.
§ For detail of notch, see Fig. 12, Reference 10.
** This value may be high, according to the results on vessels M and H.

Table 6—Limiting Membrane Stresses for Steels in a Pressure Vessel Containing Strain Raisers of Factor 4

Steel	*Yield strength*	*Tensile strength*	*Elongation (2 in.), %*	*Strain range for 100,000 cycles,* %*	*Limiting membrane stress† psi*	*% of yp,*	*% of ts,*
A201A	36,000	59,000	38.0	0.30	22,000	61.0	37.3
48s5	48,400	70,600	31.7	0.35	26,000	53.8	36.8
A302B	65,800	87,000	26.2	0.40	30,000	45.6	34.5
NES70	84,800	101,000	19.5	0.48	36,000	42.5	35.6
Navy G	79,200	95,200	25.5	0.48	36,000	45.5	37.8
J-Alloy-3	113,000	129,000	17.5	0.49	37,000	32.7	28.7
T-1	123,000	130,000	15.5	0.52	39,000	31.7	30.0

* Strain range based on Lehigh unnotched specimens.
† Limiting membrane stress = (strain range/f_e) × E = (strain range/4) × 30 × 10^6.

4. The yield strength does not serve as a satisfactory criterion of fatigue strength nor any other *combination* of tensile characteristics.

B. Geometry Factors

1. Fatigue resistance is lowered by any factor which introduces a local increase in cyclic strain. In pressure vessels, the most potent source of strain raisers appears at attachments and openings. Superimposed surface defects originating from rolling, pickling, stamping, manufacturing operations, etc., will lower fatigue strength.

2. On the basis that a constant ratio exists between the elastic membrane strain and the plastic strains in the much smaller boundary and junction regions, the average strain concentration factor, f_e, can be determined for various plate surface defects and notches and for the nozzles present in the model vessels as given in Table 5.

3. The value of $f_e = 4$ for the nozzle attachment appears too high according to elastic stress concentration data. This may be due to the small size of the model vessels, and should, therefore, be checked on a larger specimen to establish whether this is true or whether a radical difference exists between elastic and plastic strain concentration.

4. The effective strain concentration factor may not be a function of geometry alone, but may be secondarily dependent on material characteristics. Plasticity characteristics may have an effect on the constant ratio mentioned in conclusion B-2. (See Illinois data, Fig. 13, Reference 7, and Figs. 5 and 6, Reference 13.)

C. Cycling Conditions

1. Specimens designed to establish a relationship between membrane areas and the strain concentrating regions of a structure should never be loaded beyond the elastic strain range of the membrane areas. For the bending type specimen, this range may be as high as twice the yield point in the test area, but for a vessel model, the yield point in tension should not be exceeded.

2. Over a temperature range from 0 to 650° F, there appears to be very little change in the fatigue resistance of pressure vessel steels, provided no corrosive environment is present.

3. There is some evidence that fatigue resistance is lowered by a reduction in the rate of cycling. A 2000-fold reduction in cycling rate lowered the fatigue life about 15%. This is equivalent to about 8–10% less allowable strain range. This reduction seldom needs to be considered unless the total number of major cycles can be expected to be more than 60,000 during the entire service life of the vessel.

Recommendations

The tests and data included in this report are not extensive enough to make a thorough exploration of all the factors involved in plastic fatigue. The correlation of these data, however, does show basic relationships that will serve to indicate fields of further investigation which will be fruitful in more sharply defining the limiting factors for the designer. In order to derive practical value from the work so far accomplished, the following minimum effort is recommended:

1. Extend the work on model pressure vessels to include tests representing the higher strength steels under investigation by PVRC.*

2. Develop a simple test of short duration for the determination of the strain-raising factor f_e for a common discontinuity, such as a round hole.

3. Conduct tests on vessels at least three times larger than the model vessels used at École Polytechnique to compare the effect of size with the present findings.

Acknowledgments

This paper summarizes the results, most of which are published as shown in the references. The project was initiated and ably spearheaded by Perry R. Cassidy, formerly chairman of PVRC. Professor R. D. Stout (project leader) and Professor J. H. Gross conducted the investigation at Lehigh University; Professor T. J. Dolan (project leader) and Professor C. E. Bowman at the University of Illinois; and Dr. G. Welter (project leader) and Professor Julien Dubuc at École Polytechnique. I. E. Boberg was chairman of the Coordinating Committee of Pressure Vessel Research Committee guiding the plastic fatigue investigations.

In addition to the three project leaders mentioned above, W. Paul Gerhart, L. F. Kooistra, W. T. Lankford and Charles M. Schwitter were members of the Coordinating Committee during the correlation of plastic fatigue investigations.

* A302B and Navy HT-48s5, 50,000 yp range; Navy G and NES70, 70,000 yp range. J-Alloy-3 and T-1, 90,000 yp range.

References

1. Tor, S. S., Ruzek, J. M., and Stout, R. D., "Repeated Load Tests on Welded and Prestrained Steels," The Welding Journal, **31** (5), Research Suppl., 238-s to 246-s (1952).
2. Gross, J. H., Tsang, S., and Stout, R. D., "Factors Affecting Resistance of Pressure Vessel Steels to Repeated Overloading," *Ibid.*, **32** (1), Research Suppl., 23-s to 30-s (1953).
3. Gross, J. H., Gucer, D. E., and Stout, R. D., "The Plastic Fatigue Strength of Pressure Vessel Steels," *Ibid.*, **33** (1), Research Suppl., 31-s to 39-s (1954).
4. Blaser, R. U., Tucker, J. T., Jr., and Kooistra, L. F., "Biaxial Fatigue Tests on Flat-Plate Specimens," *Ibid.*, **31** (3), Research Suppl., 161-s to 168-s (1952).
5. Bowman, C. E., and Dolan, T. J., "Biaxial Fatigue Properties of Pressure Vessel Steels," *Ibid.*, **32** (11), Research Suppl., 529-s to 537-s (1953).
6. Bowman, C. E., and Dolan, T. J., "Further Studies of Biaxial Fatigue Properties of Pressure Vessel Steels," *Ibid.*, **34** (1), Research Suppl., 51-s to 59-s (1955).
7. Bowman, C. E., and Dolan, T. J., "Resistance of Low-Alloy Steel Plates to Biaxial Fatigue," *Ibid.*, **35** (2), Research Suppl., 102-s to 108-s (1956).
8. Narduzzi, E. D., and Welter, Georges, "High-Pressure Vessels Subjected to Static and Dynamic Loads," *Ibid.*, **33** (5), Research Suppl., 230-s to 238-s (1954).
9. "Some Theoretical Considerations About Fatigue Tests of Model Pressure Vessels Repeatedly Stressed in the Elastic and Semi-Plastic Range of the Material," report by Dr. G. Welter to PVRC, dated April 29, 1954 (not published).
10. Dubuc, Julien, and Welter, Georges, "Investigation of Static and Fatigue Resistance of Model Pressure Vessels," The Welding Journal, **35** (7), Research Suppl., 329-s to 337-s (1956).
11. Murphy, J. J., Soderberg, C. R., Jr., and Rossheim, D. B., "Considerations Affecting More Economic But Equally Safe Pressure Vessel Construction Utilizing Either Present-Day Ductile Materials or New High-Strength Less-Ductile Materials," API, Division of Refining **35**, (III), 258–287 (1955); also Welding Research Council Bulletin No. 27, May 1956.
12. Low, A. C., "Short Endurance Fatigue," presented at the International Conference on Fatigue of Metals, sponsored by The Institute of Mechanical Engineers in cooperation with The American Society of Mechanical Engineers in New York, Nov. 28–30, 1956.
13. Dolan, Thomas J., "Significance of Fatigue Data in Design of Pressure Vessels," The Welding Journal, **35** (5), Research Suppl., 255-s to 260-s (1956).
14. Schoessow, G. J., and Brooks, E. A., "Analysis of Experimental Data Regarding Certain Design Features of Pressure Vessels," *ASME Transactions*, **72** (5), 567–577 (1950).
15. Kooistra, L. F., and Blaser, R. U., "Experimental Technique in Pressure Vessel Testing," *Ibid.*, **72** (5), 579–589 (1950).

ALLOYS FOR BRAZING THIN SECTIONS OF STAINLESS STEEL

Suitability of silver-copper, silver-manganese and manganese-nickel brazing alloys for joining Types 304, 321 and 17–7 PH stainless steels is discussed by the author

BY A. S. McDONALD

ABSTRACT. The following brazing alloys: 72Ag – 28Cu, 72Ag – 28Cu + 0.5Li, 85Ag – 15Mn, 85Ag – 15Mn + 0.5Li and 68Mn – 32Ni are discussed as candidates for brazing thin sections of stainless steel. The results of wetting tests on Types 304, 321 and 17–7 PH stainless steel in hydrogen atmosphere at various dew points and temperatures are presented which delineate the temperature and dew point conditions necessary for satisfactory wetting of the base metals and demonstrate the effects of lithium additions in aiding wetting of the base metal and increasing the fluidity of the filler metal. Data on the base metal solution and penetration characteristics, and oxidation resistance, of the alloys are also presented.

Introduction

At the present time there is not available a single alloy with all of the characteristics desirable for brazing stainless steel sections from 0.001 to 0.010 in. thick in the fabrication of structural honeycomb panels and heat exchangers. Such an ideal alloy would wet and flow on stainless steel (in particular Type 321 and 17–7 PH) without the aid of flux in a protective atmosphere, it would not damage the base metal as a result of solution or penetration, and it would have good strength and oxidation resistance at the required service temperature.

Given minimum solution or penetration of the base metal as a mandatory condition, the commercially available brazing alloys to choose from are limited. Thus, the nickel-base alloys containing boron, which are highly desirable in other respects, must in most cases be abandoned because of their drastic solution and penetration characteristics.

This paper discusses some of the characteristics of the following alloys: 72Ag – 28Cu (with and without the addition of lithium), 85Ag – 15Mn (with and without the addition of lithium) and 68Mn – 32Ni. These alloys have in common the fact that they can be used to braze thin sections of stainless steel without the drastic base metal penetration characteristic of nickel-base alloys containing boron.

A. S. McDonald is Research Metallurgist, Handy & Harman, Bridgeport 1, Conn.

To be presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

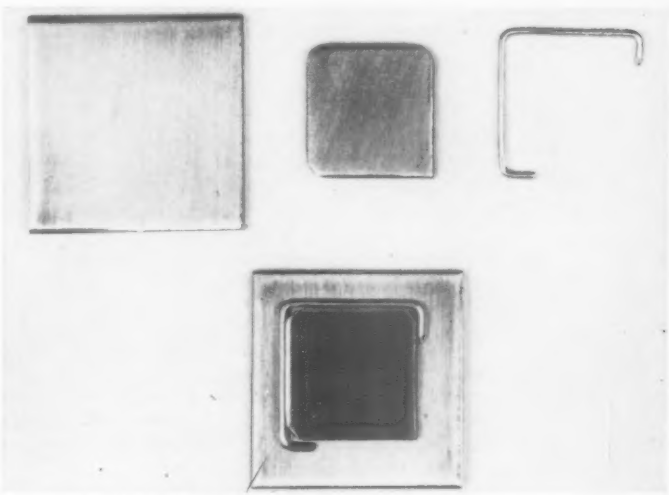


Fig. 1 Specimen used for wetting tests

Part I is devoted to the wetting characteristics of the alloys on Types 304, 321 and 17–7 PH stainless steel, and the effect of lithium additions on wetting. The conditions of temperature and dew point necessary for using the alloys in a hydrogen atmosphere are delineated.

Part II is devoted to the solution and penetration characteristics of the alloys in comparison with (1) a typical nickel-base alloy containing boron, and (2) copper.

Part III is devoted to the oxidation characteristics of the alloys.

Part IV concludes the paper with a discussion of the alloys as candidates for brazing thin sections of stainless steel.

Part I. Wetting Characteristics

Experimental Procedure

Specimens were prepared consisting of a $1^1/_4$-in. square plate of 0.062-in. gage flat-rolled steel, on top of which was placed a $^3/_4$-in. square of the same base metal. A slightly oversized elbow, $^3/_4$-in. on a side, formed from 0.047-in. diam filler metal wire was placed around two adjacent sides of the top plate, and the two ends of the elbow bent around the opposite two sides for security. The specimen is illustrated in Fig. 1. The specimens were washed with acetone and the base-metal surfaces abraded with emery cloth.

The specimens were brazed in the small laboratory globar furnace illustrated in Fig. 2. Tank hydrogen was passed through a conventional palladium catalyst deoxidation unit in which any oxygen present was converted to water, and then through a commercial activated alumina drying tower. The gas delivered from the drying tower was at a dew point of −70° F or drier. Dew points were determined with a Type 7000 U Alnor dew pointer. Variation in dew point was achieved by putting a water bottle in parallel with the dry gas line and adjusting the fraction of gas bubbling through the water bottle

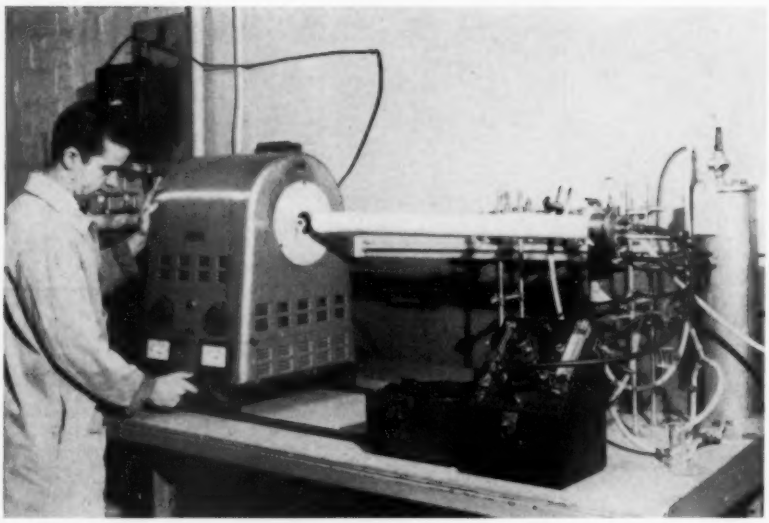


Fig. 2 Experimental brazing furnace

until the desired dew point was attained.

In a typical run the specimens were loaded in the cold muffle and the entrance port closed. Gas entered through a tube extending from the entrance port to the back end of the muffle. A closed end tube carried a thermocouple to a point directly under the specimens. A third tube extended to a point directly over the specimens and from this tube gas samples were taken for all dew point determinations. Thus, the dew points recorded represent the humidity of the gas in the muffle at a point near the work. The muffle was purged with nitrogen, hydrogen was admitted and the relative fractions of dry and humidified gas were adjusted until the dew point desired in a particular run was attained. The furnace, which had been preheated to the brazing temperature, was then rolled over the muffle. It usually took about 10 min for the specimens to come up to brazing temperature. The specimens were held at brazing temperature for 10 min after which the furnace was rolled away and the muffle cooled under a fan. Temperatures, determined by the thermocouple directly under the specimens, and dew points of atmosphere samples withdrawn from the tube extending into the muffle to a point directly over the specimens, were taken throughout the brazing cycle at intervals of from 1 to 2 min. There was usually a surge in moisture content during the heating period due to the bake-out of adsorbed moisture in the system but in all cases the dew point returned to its original steady value before the melting temperature of the filler metal was reached.

72Ag – 28Cu With and Without Lithium on Type 304 Stainless Steel

In Fig. 3 the specimens are arranged in the order of ascending temperature on the ordinate and increasing moisture content on the abscissa. At constant temperature, conditions go from oxidizing to reducing in the direction of decreasing moisture content. At constant dew point, conditions go from oxidizing to reducing in the direction of ascending temperature. Thus, conditions are reducing toward the upper left-hand region of the figure and oxidizing toward the lower right-hand region. This array of specimens delineates the area wherein conditions are sufficiently reducing to allow 72Ag – 28Cu to wet and flow on Type 304 stainless steel.

In Fig. 4 we have a similar array of specimens involving 72Ag – 28Cu plus a 0.5% addition of lithium. On comparing the two sets of specimens it is clearly seen that in the upper left-hand region the Li addition has increased the fluidity

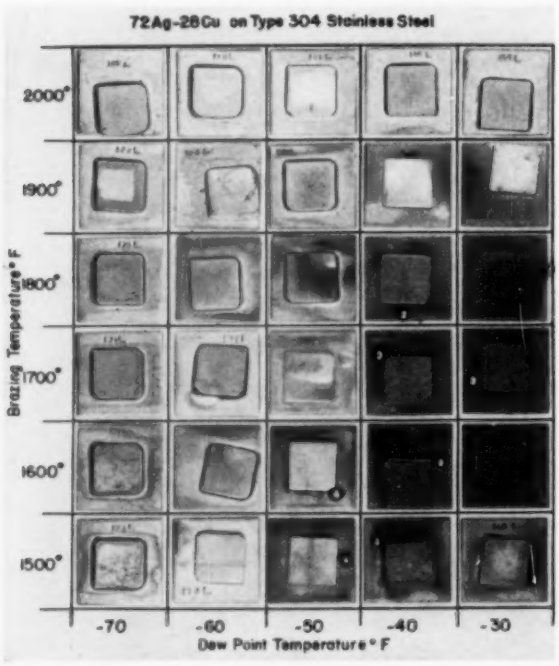


Fig. 3 The wetting characteristics of 72Ag – 28Cu on Type 304 stainless steel in hydrogen

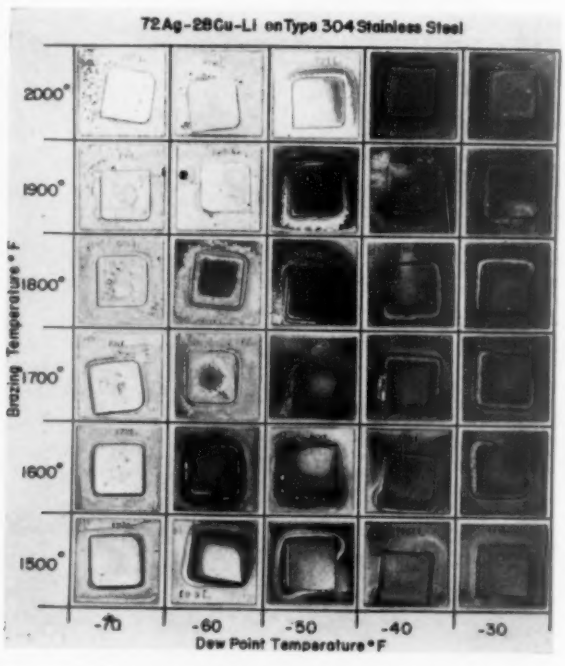


Fig. 4 The wetting characteristics of 72Ag – 28Cu + 0.5 Li on Type 304 stainless steel in hydrogen

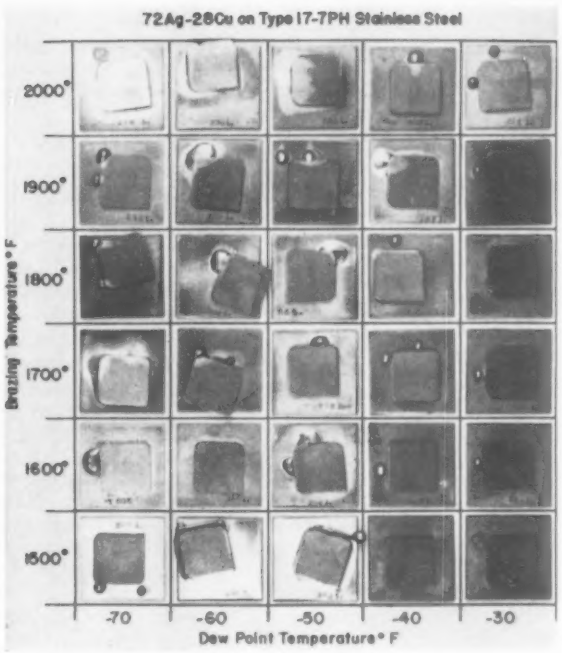


Fig. 5 The wetting characteristics of 72Ag – 28Cu on 17 – 7 pH stainless steel in hydrogen

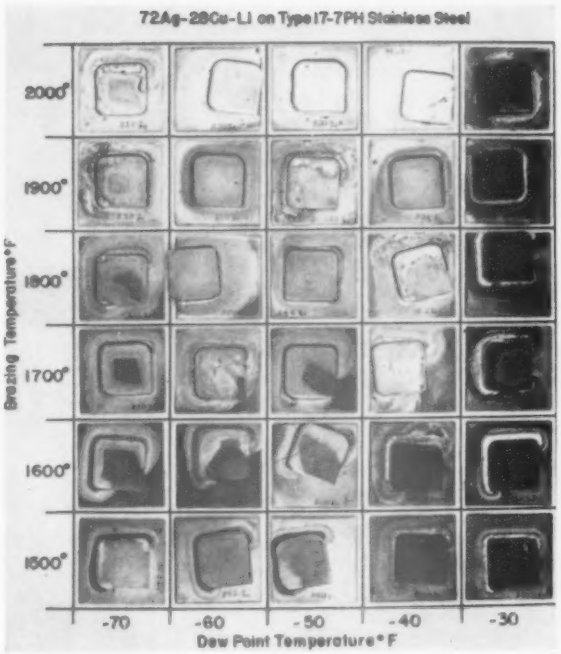


Fig. 6 The wetting characteristics of 72Ag – 28Cu + 0.5 Li on 17 – 7 pH stainless steel in hydrogen

of the filler metal, and in the lower right-hand region, where the base metal was so badly oxidized that straight Ag-Cu completely spheroidized, the Li addition has deoxidized the surface of the base metal sufficiently to allow the filler metal to wet and bond although the fluidity of the filler metal in this region is poor. This is in accordance with the findings of Bredzs and Canonico[1] who report that lithium additions to brazing alloys will deoxidize the surface of the base metal and reduce the wetting angle.

If we compare the two sets of specimens at −60° F dew point in the 1500 to 1600° F temperature range, −50° F dew point in the 1700 to 1900° F range, −40° F dew point in the 1900 to 2000° F and −30° F dew point at 2000° F, we can find cases where the oxidation of the base metal is negligible or very slight, and where straight Ag-Cu displays good fluidity whereas the lithium-bearing modification is definitely sluggish. Since the fact that straight Ag-Cu flows in these cases demonstrates that the surface of the base metal is free of flow-inhibiting oxide films we attribute the sluggish behavior of the lithium-bearing modification to the reaction of lith-

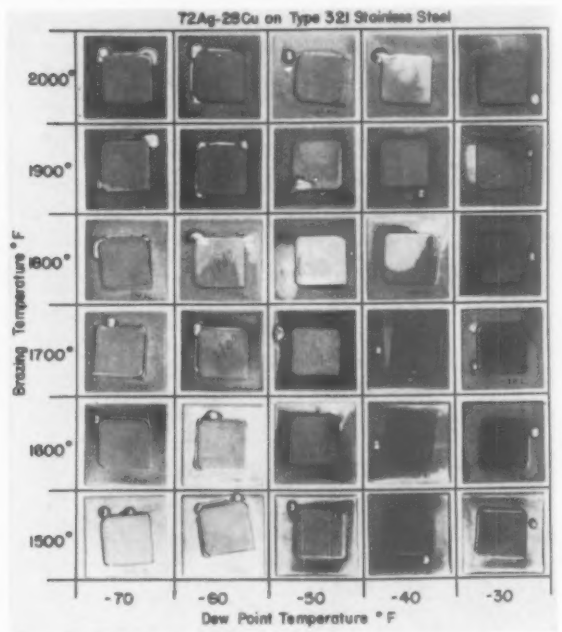


Fig. 7 The wetting characteristics of 72Ag – 28Cu on Type 321 stainless steel in hydrogen

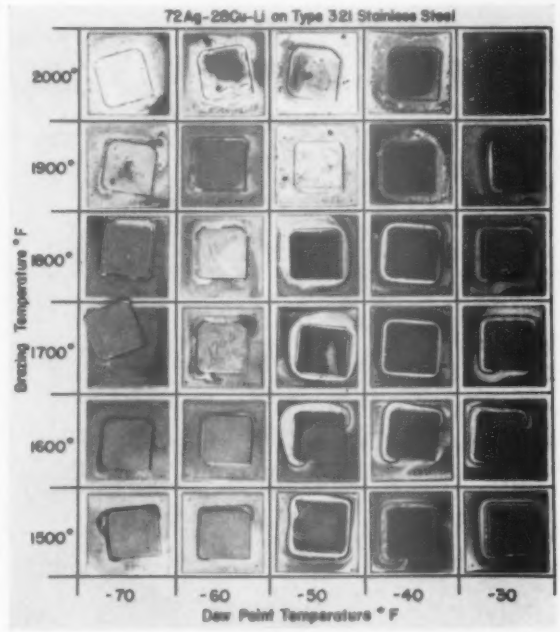


Fig. 8 The wetting characteristics of 72Ag – 28Cu + 0.5 Li on Type 321 stainless steel in hydrogen

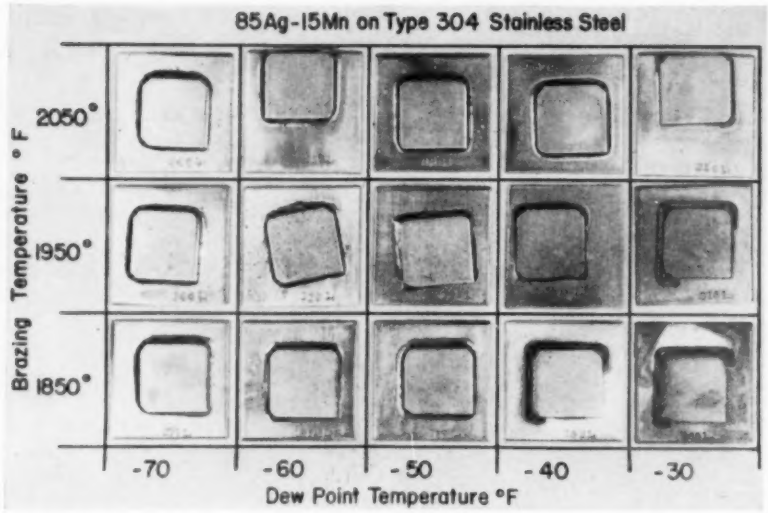


Fig. 9 The wetting characteristics of 85Ag – 15Mn on Type 304 stainless steel in hydrogen

ium in the filler metal with the moisture in the atmosphere.

These specimens demonstrate the effect of lithium as a deoxidizer and wetting agent, and bring out the very important practical consideration that, in order to realize the full benefit of a Li addition in hydrogen furnace brazing, one must have a reasonably dry atmosphere to begin with.

72Ag – 28Cu With and Without Lithium on 17-7 PH Stainless Steel

In Fig. 5 we have an array of specimens involving 72Ag – 28Cu on 17–7 PH stainless steel. Because of the aluminum content of this steel it is much more difficult to braze in atmosphere without flux than Type 304. A comparison of Figs. 3 and 5 illustrates the difference.

In Fig. 6 we have a similar array of specimens involving 72Ag – 28Cu plus a 0.5% addition of lithium. The beneficial effect of the Li addition in this case is striking. Indeed, a comparison of the two figures indicates that it is practically impossible to braze 17–7 PH stainless steel with straight 72Ag – 28Cu under any of the conditions of temperature and dew point studied. Again, consideration of the specimens in the lower right-hand region indicates that a reasonably dry atmosphere is necessary for the lithium addition to be practically effective.

72Ag – 28Cu With and Without Lithium on Type 321 Stainless Steel

In Fig. 7 we have an array of specimens involving straight 72Ag – 28Cu on titanium-bearing Type 321 stainless steel and in Fig. 8 a similar array involving 72Ag – 28Cu plus a 0.5% addition of lithium. In this case the lithium addition has to some extent promoted wetting. However, the fluidity of the lithium modification is relatively poor compared with the 17–7 PH case. This result is rather surprising because a comparison of the free energies of formation of aluminum oxide and titanium oxide indicates that the aluminum oxide is the more stable of the two,[2] and one would expect that if lithium were able to reduce an interfering skin of aluminum oxide on 17–7 PH strainless steel, then certainly an interfering skin of titanium oxide on Type 321 stainless steel should be reduced. In view of the behavior of 72Ag – 28Cu + Li on 17–7 PH stainless steel the behavior of 72Ag – 28Cu + Li on Type 321 stainless steel is anomalous.

In the section below which discusses the behavior of 85Ag – 15Mn with and without lithium on Type 321 stainless steel, specimens are presented which indicate that in the case of 85Ag – 15Mn the lithium modification does promote wetting of Type 321 stainless steel in the expected manner.

85Ag – 15Mn With and Without Lithium on Type 304 Stainless Steel

In Fig. 9 we have an array of specimens involving 85Ag – 15Mn on Type 304 stainless steel. In the case of this filler metal, flow may be inhibited both by the oxidation of the base-metal surface and the oxidation of manganese in the filler metal itself. In the lower right-hand region of the figure a manganese oxide skin around the filler metal wire can be seen. With increasing temperature or decreasing moisture content, the oxide skin is reduced.

In Fig. 10 we have a similar array of specimens involving 85Ag – 15Mn plus a 0.5% addition of lithium. The effect of lithium as a wetting agent can be seen in the upper left-hand region, and the effect of lithium as a deoxidizer can be seen in the lower right-hand region where the lithium has deoxidized the manganese oxide skin on the filler-metal wire surface.

85Ag – 15Mn With and Without Lithium on 17–7 PH Stainless Steel

In Fig. 11 we have an array of specimens involving 85Ag – 15Mn on 17–7 PH stainless steel. Here we can observe the effect of the oxidation of the base metal surface and the oxidation of manganese in the filler metal in inhibiting flow. In the lower right-hand region a skin of manganese oxide can be seen on the surface of the filler-metal wire. In the upper left-hand region the filler metal is bright and free of surface oxide but wetting is poor because of the interference of aluminum oxide on the base-metal surface.

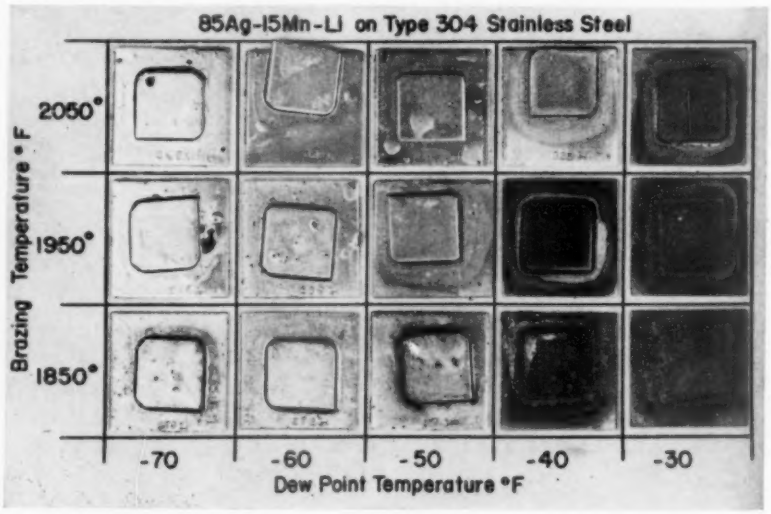
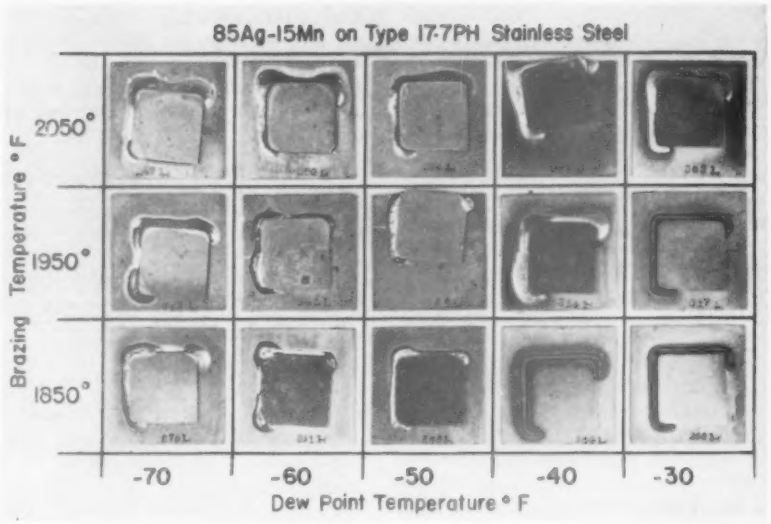


Fig. 10 The wetting characteristics of 84Ag – 15Mn + 0.5 Li on Type 304 stainless steel in hydrogen

Fig. 11 The wetting characteristics of 85Ag – 15Mn on 17 – 7 pH stainless steel in hydrogen →



In Fig. 12 we have a similar array of specimens involving 85Ag – 15Mn plus a 0.5% addition of Li on 17–7 PH stainless steel. The effect of lithium as a deoxidizer and wetting agent is again demonstrated.

85Ag – 15Mn With and Without Lithium on Type 321 Stainless Steel

In Fig. 13 we have an array of specimens involving 85Ag – 15Mn on Type 321 stainless steel. In the lower right-hand region a manganese oxide skin can be seen on the surface of the filler-metal wire. In the upper left-hand region the filler metal is bright and free of surface oxide but due to the interference of titanium oxide on the base-metal surface, flow is poor. In Fig. 14 a similar array of specimens involving 85Ag – 15-Mn plus a 0.5% addition of lithium again demonstrates the effect of lithium as a deoxidizer and wetting agent.

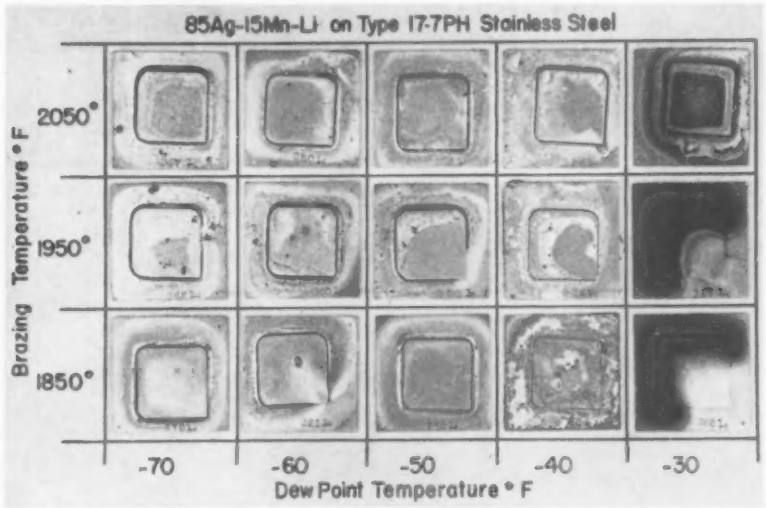


Fig. 12 The wetting characteristics of 85Ag – 15Mn + 0.5 Li on 17 – 7 pH stainless steel in hydrogen

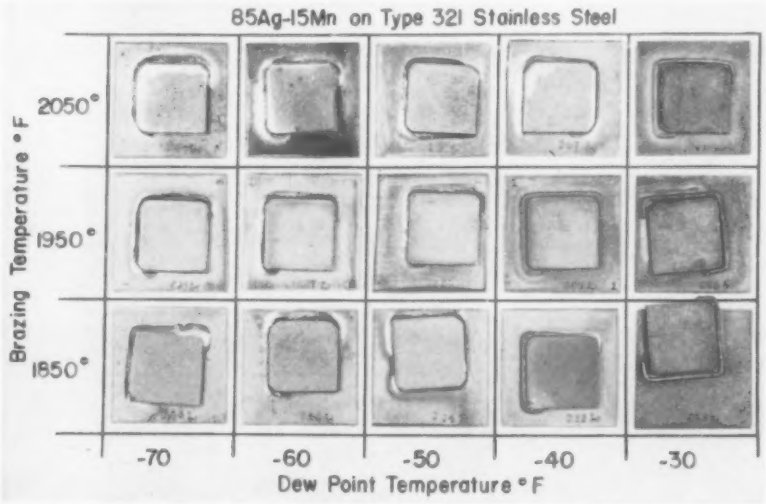


Fig. 13 The wetting characteristics of 85Ag – 15Mn on Type 321 stainless steel in hydrogen

68Mn – 32Ni

In Figs. 15, 16 and 17, we have specimens involving 68Mn – 32Ni on the three base metals. In all cases it can be seen that at moisture content below about −50° F dew point at 1950° F and about −40° F dew point at 2050° F the manganese oxide skin on the surface of the filler metal was reduced and the filler metal wet and flowed on the base metal. Under these conditions good flow on Type 304 stainless steel would be expected. The flow of 68Mn – 32Ni on 17–7 PH and 321 is better than the flow of straight 72Ag – 28Cu or 85Ag – 15Mn on these base metals under similar conditions of temperature and dew point, and generally better than one might expect since the oxides of aluminum and titanium will certainly not be reduced by hydrogen under the conditions of temperature and dew point maintained in the experiment.

Part II. Solution and Penetration Characteristics

In the brazing of thin stainless steel parts, the solution of base metal by molten filler metal and the penetration of filler metal into the base metal may sometimes be so severe as to cause perforation or partial destruction of the part being brazed. The extent of reaction between filler metal and base metal depends upon the composition of the two metals, brazing cycle and filler metal placement. The brazing cycle determines the time and temperature factors and the filler metal placement determines the availability of filler metal for reaction. If long brazing cycles are employed which result in molten filler metal being in contact with the base

metal for long periods of time at high temperatures more damage can be expected than if short cycles are used. If filler metal placement is poor or an excess of filler metal is used resulting in accumulations of excess molten filler metal, perforation of the base metal may occur. These factors make it difficult to say whether or not a given filler metal which reacts with a given base metal can or cannot be used successfully—so much depends upon the particular assembly and the technique employed.

However, those filler metals which do not significantly react with a given base metal can be separated from those which do. In the case of filler metals which do react with the base metal some are more damaging than others and their relative characteristics can be discussed.

In order to compare the solution and penetration characteristics of the three filler metals under discussion with some alternative alloys, specimens were prepared from $^3/_8$-in. round Type 304 stainless-steel rod. Cylinders $^3/_4$ in. long were cut from the round stock and a hole was drilled along the longitudinal axes of the specimens to a depth of $^5/_8$ in. The holes were reamed to 0.125 ± 0.0005 in., and filled with the filler metals listed in Table 1 in the form of powder or chips. The specimens were then heated to 2050° F in hydrogen and soaked at that temperature for 1 hr.

In these specimens the amount of filler metal available per unit surface of base metal was excessive, and the full hour soak at temperature was long, compared with normal brazing practice. Thus, where reaction between the filler metal and base metal was slight or not detectable in the specimens, reaction between filler metal and base metal would be negligible in brazing. On the other hand, where reaction did occur the extent of reaction in these specimens is greater than would be expected in brazing.

After heat treatment the specimens were sectioned transversely and examined on the metallograph. The diameter of the hole filled with filler metal was measured at low magnification (×60) and any increase in diameter indicated solution of the base metal in the molten filler metal. The base metal/filler metal interface was then examined at high magnification (×500) and any penetration of the solid base metal was measured. The results are listed in Table 1 and discussed below.

85Ag – 15Mn and 85Ag – 15 Mn + 0.5Li

These alloys do not dissolve nor penetrate stainless steel. Figure 18 illustrates the 85Ag – 15Mn/base metal interface and is typical of the two filler metals. These alloys can be used to braze thin sections without danger of damage to the base metal.

72Ag – 28Cu and 72Ag – 28Cu + 0.5Li

These alloys do not dissolve stainless steel. Slight erosion of the base metal surface may occur as illustrated in Fig. 19 which shows the 72Ag – 28Cu/base metal interface. However, even under the drastic conditions under which the specimen was prepared, which included a soaking temperature more than 500° F above the usual brazing temperature for

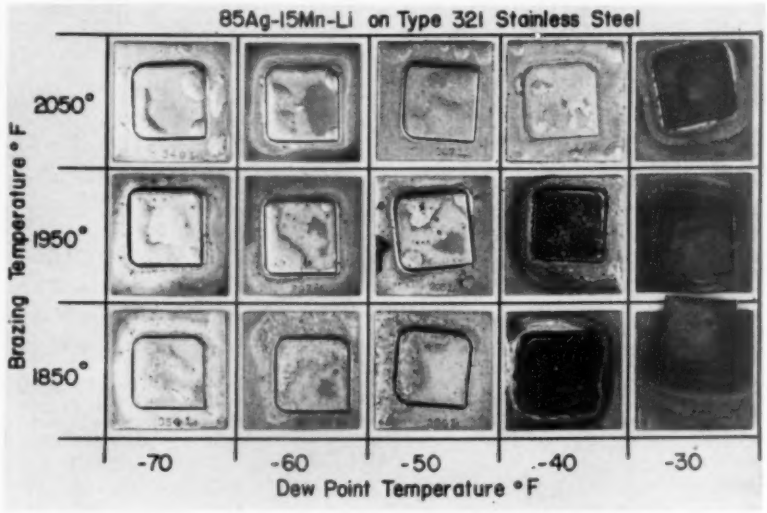


Fig. 14 The wetting characteristics of 85Ag – 15Mn + 0.5 Li on Type 321 stainless steel in hydrogen

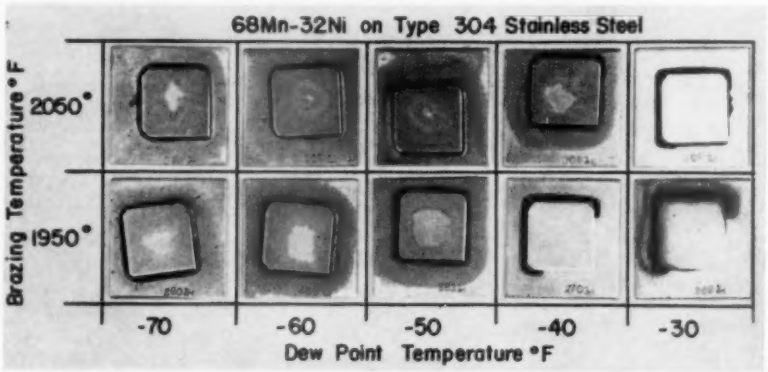


Fig. 15 The wetting characteristics of 68Mn – 32Ni on Type 304 stainless steel in hydrogen

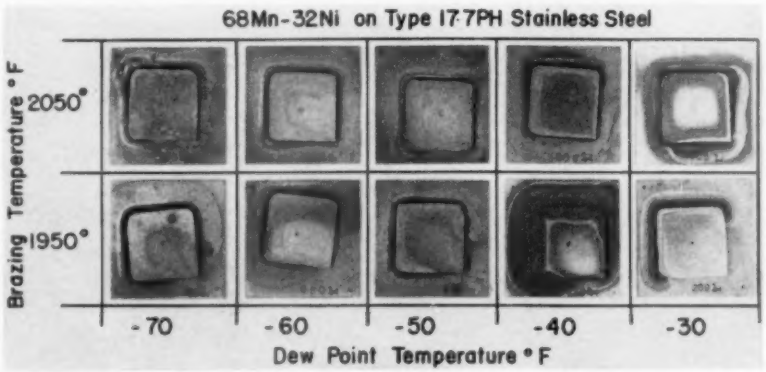


Fig. 16 The wetting characteristics of 68Mn – 32Ni on 17 – 7 pH stainless steel in hydrogen

Table 1—Measurements of Solution and Penetration of Stainless-Steel Base Metal After Exposure to Molten Filler Metals for 1 Hr

Filler metal	d_1, *in.*	d_2, *in.*	S, *in.*	p, *in.*	D, *in.*
72Ag – 28Cu	0.125	0.125	None	<0.001	<0.001
72Ag – 28Cu + 0.5Li	0.125	0.125	None	<0.001	<0.001
85Ag – 15Mn	0.125	0.125	None	None	None
85Ag – 15Mn + 0.5Li	0.125	0.125	None	None	None
68Mn – 32Ni	0.125	0.131	0.003	None	0.003
Copper	0.125	0.127	0.001	0.003	0.004
82Ni – 7.0Cr – 4.5Si – 2.9B (4.5 others, mostly Fe)	0.125	0.137	0.006	0.008	0.014

d_1 = original diameter of well ±0.0005 in. d_2 = diameter of alloy filled well after soaking at 2050° F for 1 hr. $s = (d_2 - d_1)/2$ indicates the amount of base metal dissolved by the filler metal at one interface. p = depth of filler metal penetration into base metal. $D = s + p$ provides a qualitative picture of the total effect upon the base metal.

72Ag – 28Cu, the depth of the affected area is less than 0.001 in. These alloys can be used to braze thin sections with very little danger of damage to the base metal.

68Mn – 32Ni

This alloy will dissolve stainless steel. Table 1 indicates that a layer of stainless steel in the order of 0.003 in. thick was dissolved from the surface of the base metal. As discussed previously, the specimens were prepared under severe conditions and the thickness of base metal layer dissolved cannot be taken as a typical value. However, the fact that the filler metal can react with the base metal to this extent indicates that caution is necessary in using the alloy to braze very thin sections. Under conditions where the brazing cycle is very long and excessive accumulations of filler metal can occur as a result of poor filler metal preplacement, serious reduction in the thickness of the base metal, and in the extreme case perforation, may result. Figure 20 shows the 68Mn – 32Ni/base metal interface. Although this filler metal will dissolve stainless-steel base metal it is not characterized by the deep base-metal penetration typical of the nickel-base alloys containing boron, or the intergranular erosion typical of copper.

Ni-Cr-Si-B and Copper

Data on copper and the alloy 82.1Ni – 7.0Cr – 4.5Si – 2.9B are included as a basis for comparison. It is well known that the nickel-base alloys containing boron are characterized by severe penetration of stainless-steel base metal. Table 1 indicates that a layer of base metal 0.006 in. thick was dissolved from the surface of the specimen and that further penetrations of base metal to a depth of 0.008 in. occurred. Figure 21 shows the Ni-Cr-Si-B/base metal interface.

Copper dissolved a layer of base metal about 0.001 in. thick and in addition intergranular erosion to a depth of about 0.003 in. occurred. Figure 22 shows the copper/base metal interface.

Part III. Oxidation Characteristics

For most practical purposes the oxidation rate of a metal or alloy can be expected to follow a parabolic relationship of the form $x^2 = kt$, where x is the thickness of the oxidized zone, t is the time and k is a constant. The parabolic curves in Figs. 23, 24 and 25 were constructed using calculated values of the oxidation rate constant, k, based on weight gain determinations and metallographic examination of specimens of the filler metal alloys which were exposed to still air for times up to 1000 hr. The details of the experimental method and the theory upon which it is based will be found in the Appendix.

No practical difference between the oxidation rate of 72Ag – 28Cu and 72Ag – 28Cu + 0.5Li was detected. Both alloys develop a superficial scale of copper oxide, and a complex internal oxidation zone consisting of copper oxide, fine silver and porosity. Figure 26 shows the 72Ag – 28Cu + 0.5Li specimen after exposure at 1000° F for 1000 hr.

In the case of 85Ag – 15Mn some superficial scale forms in the early stages of oxidation after which the manganese is internally oxidized resulting in masses of manganese oxide in a matrix of fine silver. Figure 27 shows the 85Ag –

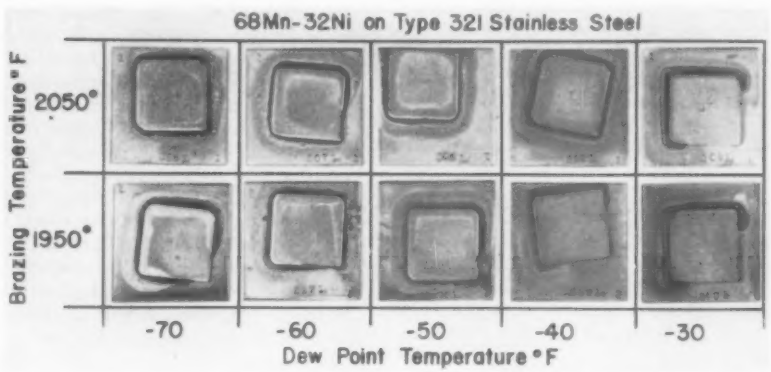


Fig. 17 The wetting characteristics of 68Mn – 32Ni on Type 321 stainless steel

Fig. 18 85Ag – 15Mn/Type 304 stainless steel interface after soaking at 2050° F for 1 hr. X 200

Fig. 19 72Ag – 28Cu/Type 304 stainless steel interface after soaking at 2050° F for 1 hr. X 200

Fig. 20 68Mn – 32Ni/Type 304 stainless steel interface after soaking at 2050° F for 1 hr. X 200

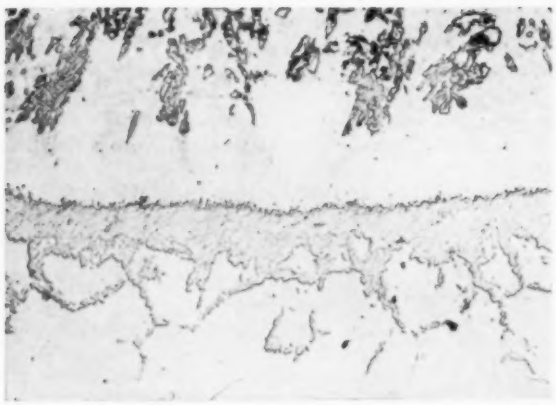


Fig. 21 Ni-Cr-Si-B/Type 304 stainless steel interface after soaking at 2050° F for 1 hr. X 200

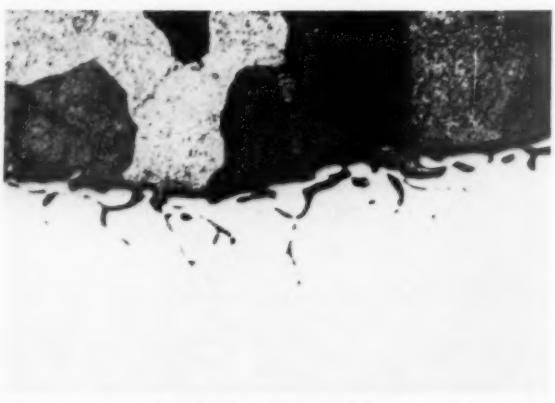


Fig. 22 Copper/Type 304 stainless steel interface after soaking at 2050° F for 1 hr. X 200

15Mn specimen after exposure at 1000° F for 1000 hr.

In Fig. 28, which shows the 68Mn – 32Ni specimen after exposure at 1000° F for 1000 hr, a surface scale together with a zone of internal oxidation can be observed.

In deciding whether or not a prospective brazing alloy will have adequate oxidation resistance in a given application it is usually necessary for the design engineer to base his decision on a knowledge of the behavior of prototypes exposed to simulated service conditions.

These curves are intended to orient the design engineer with respect to whether or not the oxidation characteristics of the alloys discussed are obviously inadequate for his application or whether they show possibility.

The reader should bear in mind that the curves indicate the average thickness of scale plus internal oxidation zone as determined under laboratory conditions at constant temperature. In actual service metal parts are subjected to various temperatures and temperature cycles. In going through temperature cycles the surface scale may spall because of the difference in the thermal expansion characteristics of the metal and the scale. This will result in fresh areas of metal being exposed to the atmosphere which will accelerate oxidation damage. Furthermore, in the case of an actual brazed joint in service, the joint may fail as a result of oxidation along the interface between the filler metal and the base metal, as well as through the progressive deterioration of the bulk fillet. Also, there will be an area around the periphery of the fillet where the filler metal is very thin, although the fillet may be quite massive elsewhere. In such areas the filler metal will oxidize through to the base metal long before the bulk of the fillet is damaged.

In short, although the curves presented are quantitative they can only be used in a qualitative way in estimating the suitability of a prospective alloy. The final decision must be based on the behavior of prototype joints under conditions simulating those expected in service.

Part IV. Discussion

Silver-Copper

The data presented on 72Ag – 28Cu can, in most cases, be considered typical for silver-rich, silver-copper alloys in general. Such alloys have the advantage that they can be used to braze thin sections of stainless steel with negligible solution or penetration of base metal. Silver-rich, silver-copper alloys with an addition of lithium to enhance wetting are particularly attractive for brazing honeycomb panels of 17–7 PH stainless steel. In the past year many such panels have been brazed using alloys of this type containing from 0.1 to 0.5% lithium. A certain amount of lithium is necessary for adequate wetting. However, with increasing lithium content the alloys become increasingly fluid. Excessive fluidity may result in objectionable filleting characteristics. This raises a question as to what minimum amount of lithium is necessary to achieve adequate wetting but not produce excessive fluidity. Complete data on the relative fluidity and wetting characteristics of alloys with various lithium contents are not available at this time and the question of optimum lithium content is an open one. Further work on this problem is in progress.

Silver-Manganese

Silver-manganese can be used to braze thin sections of stainless steel without solution or penetration of base metal, and with an addition of lithium to improve wetting, can be used to furnace braze Type 321 and 17–7 PH stainless steel in hydrogen without the aid of flux. The most serious shortcoming of silver-manganese may be the fact that it is subject to crevice corrosion.[3] During the past year several companies have prepared silver-manganese brazed honeycomb panels of 17–7 PH stainless steel and exposed the assemblies to various corrosion tests. The results of these tests have been conflicting. Some investigators have reported satisfactory results and some complete failure. This matter of crevice corrosion is not yet resolved to the satisfaction of all concerned. Our own observations show that silver-manganese brazed joints are subject to crevice corrosion.

Manganese-Nickel

Although 68Mn – 32Ni will dissolve stainless-steel base metal it is by no means as severe in this respect as copper or the nickel-base alloys containing boron. Comparisons of Figs. 20 and 22 show that 68Mn – 32Ni tends to dissolve the base metal in a uniform manner whereas copper is characterized by intergranular attack. If a minimum amount of filler metal is employed 68Mn – 32Ni can probably be used to braze thin sections successfully. It has somewhat better oxidation resistance than either the silver-rich, silver-copper alloys or silver-manganese, and its ability to wet and flow on Type 321 and 17–7 PH stainless steel in dry hydrogen without the aid of flux is fairly good.

Appendix

Derivation of Oxidation Curves

For most practical purposes the oxidation rate of a metal or alloy at constant temperature can be expected to follow a parabolic relationship of the form $x^2 = kt$, where x is the thickness of reacted material (scale thickness, thickness of internal oxidation zone or both together), t is the time and k is a constant. This follows from the consideration that progressive oxidation involves the diffusion of electrons, anions and cations through an oxidized zone. The rate of diffusion through the zone is inversely proportional to the thickness of the zone, and the rate of growth of the zone,

dx/dt, is proportional to the rate of diffusion, thus: $dx/dt = k/x$ which integrates to $x^2 = kt$ (where k now includes the factor 2, resulting from the integration). The constant k, is related to temperature through the Arrhenius relation: $k = Aexp\,(-Q/RT)$, where T is the absolute temperature, R is the gas constant, Q is the activation energy and A is a constant, from which it follows that a plot of log k versus $1/T$ will be a straight line. Thus, if k is determined for a number of temperatures and a log k versus $1/T$ plot made, the value of k for intermediate temperatures can be taken from the plot and used to construct parabolas relating the oxidation depth versus time for constant temperature.* Further details of oxidation theory can be found in the standard references.[4, 5]

Specimens consisting of cylinders $1^1/_4$ in. long by $^3/_8$ in. diam were machined from castings of 72Ag – 28Cu, 72Ag – 28Cu + 0.5Li, 85Ag – 15Mn and 68Mn – 32Ni. The specimens were exposed to still air at 600, 800 and 1000° F for 1000 hr. The specimens were weighed periodically during the first 250 hr and the increase in weight per unit of surface was calculated. These weight gain measurements were related to the depth of oxidation in the following manner. If we have a metal, Me, which forms on its surface the oxide Me_xO_y, and if on exposure a unit surface of the metal increases in weight by the amount Δm due to the oxidation of Me to Me_xO_y, then the distance Δd that the oxide/metal interface has moved from the original metal surface during the exposure is given by the expression: $\Delta d = \Delta m(x \cdot W_{Me}/y \cdot W_O)\,(1/D_{Me})$, where W_{Me}, W_O and D_{Me} are, respectively, the mole weight of the metal, the mole weight of oxygen and the density of the metal. In the case of 72Ag – 28Cu it was assumed that any gain in weight was due to the formation of CuO. The density factor, D_{Me}, was taken as 28% of the density of the 72Ag – 28Cu alloy which corresponds to the weight of Cu in a unit volume of the alloy. In the case of 85Ag – 15Mn it was assumed that any weight increase was due to the formation of Mn_3O_4. The density factor was taken to be 15% of the density of the 85Ag – 15Mn alloy which corresponds to the density of Mn in the alloy. In the case of 68Mn – 32Ni it was assumed that any gain in weight was due to the formation of Mn_3O_4. The density factor was taken to be 68% of the 68Mn – 32Ni alloy which

* This assumes that Q is not only constant but identical throughout the temperature interval considered. If Q changes at one or more temperatures within the interval (as it would, for instance, in an oxidation process where below some characteristic temperature the oxide formed is of the type MeO, and above takes the form Me_xO_y) the complete log k versus $1/T$ plot would consist of two or more intersecting straight lines each with its characteristic slope.

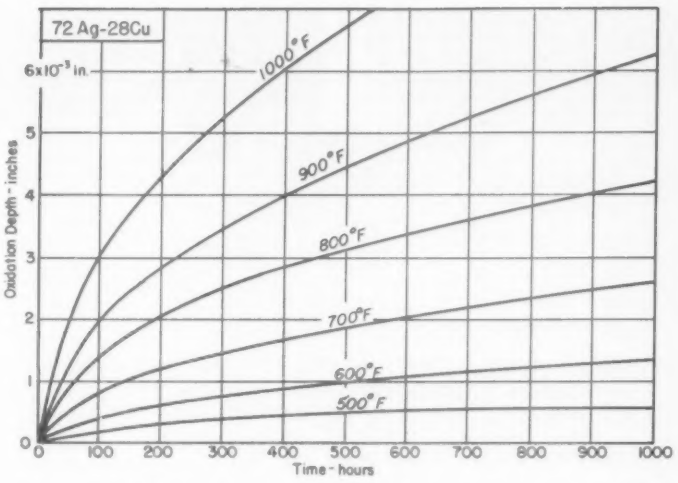


Fig. 23 Oxidation characteristics of 72Ag – 28Cu (with or without the addition of 0.5% Li)

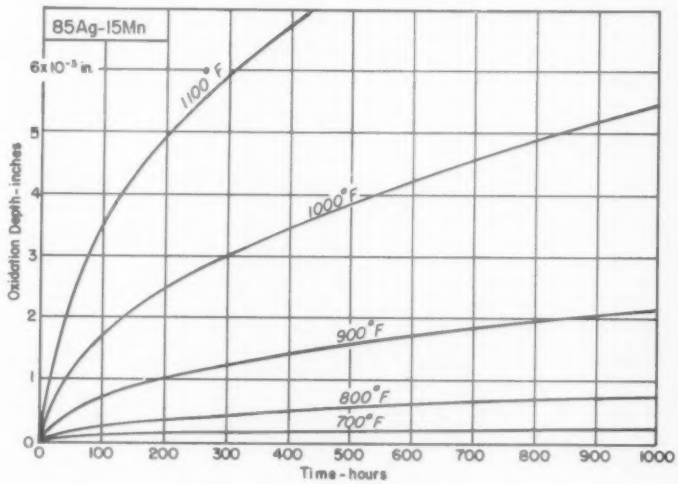


Fig. 24 Oxidation characteristics of 85Ag – 15Mn

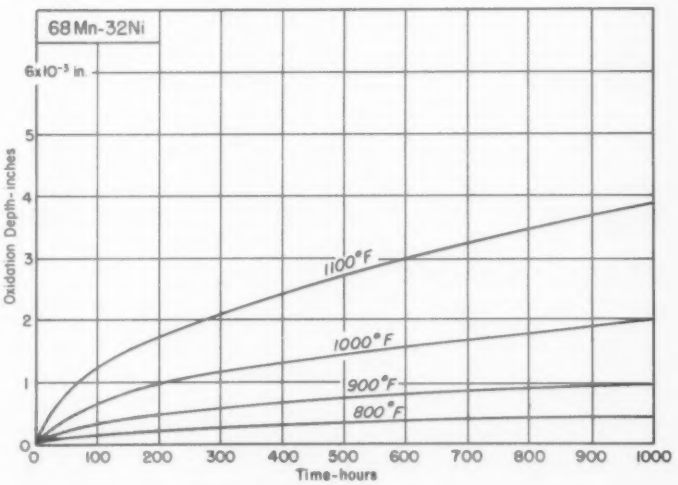


Fig. 25 Oxidation characteristics of 68Mn – 32Ni

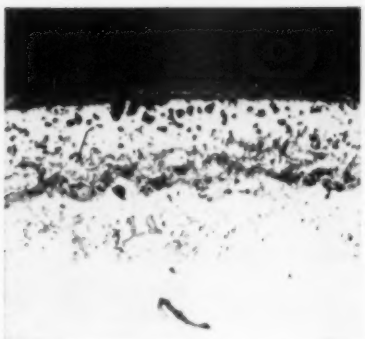


Fig. 26 Section of 72Ag – 28Cu + 0.5 Li after oxidation in still air at 1000° F for 1000 hr. X 100

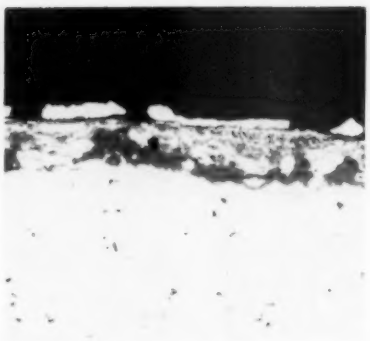


Fig. 27 Sections of 85Ag – 15Mn after oxidation in still air at 1000° F for 1000 hr. X 100

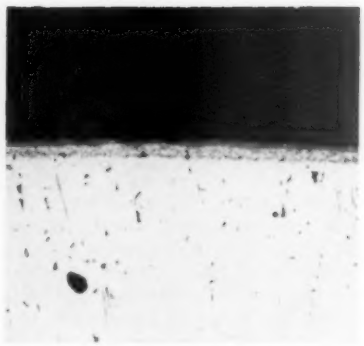


Fig. 28 Section of 68Mn – 32Ni after oxidation in still air at 1000° F for 1000 hr. X 100

corresponds to the density of Mn in the alloy.

After 1000 hr of exposure the specimens were examined under the microscope, and the average thickness of scale plus internally oxidized metal was measured. These values of the depth of oxidation, x, as determined by both weight gain measurements and microscopic examination, at various times, t, were used to calculate k in the expression $x^2 = kt$. The calculated values of k for the three temperatures were used to construct a log k versus $1/T$ plot. From this plot, values of k at 500, 600, 700, 800, 900 1000 and 1100° F were taken, and used to construct the curves in Figs. 23, 24 and 25.

Bibliography

1. Bredzs, N., and Canonico, D., "Lithium Additions to Brazing Alloys," THE WELDING JOURNAL, **34** (11), Research Suppl. 535-s to 543-s (1955).

2. Coughlin, James P., *Heats and Free Energies of Formation of Inorganic Oxides*, Bureau of Mines Bulletin 542.

3. Handy & Harman Technical Bulletin No. T-9, *Crevice Corrosion in Brazed Joints in Stainless Steel*.

4. Kubachewski and Hopkins, *Oxidation of Metals and Alloys*, Academic Press, New York (1953).

5. Jost, *Diffusion in Solids, Liquids, Gases*, Academic Press, New York (1952).

THE INFLUENCE OF BUILDING UP BY ARC WELDING ON THE FATIGUE STRENGTH OF MEDIUM-CARBON-STEEL SHAFTS

At the suggestion of the International Institute of Welding, pulsating tension fatigue tests were made on 2-in. diam steel shafts built up with a single layer of 7016 electrode weld metal. The shaft contained 0.36 C, 0.58 Mn, 0.26 Si. The weld metal was applied in the direction of the axis of the shaft which was trurned 90 or 180° after each bead. The preheat was 572° F and stress relief was at 1200° F for 2 hr. The fatigue strength of the unwelded steel was 48,500 psi, based on 5 million cycles. The welded shafts had a fatigue strength close to 37,000 psi. The fractures of the welded shafts occurred at one or both ends of the build up. In one instance, fracture started at porosity in the weld metal.

Abstract by **Gerald E. Claussen,** Linde Air Products Co., of: "De Invloed Van Het Oplassen Door Middel van Het Booglassen Met de Hand of de Vermoeiingssterkte van Assen Vervaardigd van Staal QMC30," published in Lastechniek, **22,** 195–200 (1956), a report of the Netherlands Welding Research Committee.

THE WELDING OF LOW Cr-Mo STEELS IN THE PETROLEUM INDUSTRY,

by F. F. Ates, L. Capel and C. P. M. Kym

An experimental study of the preheat and electrode requirements is given for a steel containing 0.13 C, 0.70 Mn, 0.13 Si, 0.53 Cr and 0.38 Mo in two thicknesses: $^5/_8$ and $1^3/_{16}$ in. The Lehigh system and the Controlled Thermal Severity Test were in good agreement in predicting the required preheat temperature and minimum amperage, which turned out to be 81 amp. Of five electrodes in the CTS test only one was free from weld cracks when welded in the open air without preheat. This electrode deposited weld metal containing 0.08 C, 0.90 Mn, 0.50 Cr and 0.60 Mo. Field tests are in progress based on the laboratory results.

Abstract by **Gerald E. Claussen,** Linde Air Products Co., of "Het Lassen van Laaggelegeerd Cr/Mo-Staal Voor Installaties Gebruikt in de Aardolie-Industrie," published in *Lastechniek*, **22,** 181–186 (1956). The authors are with Royal Shell, the State Railways and the Netherlands Dock and Shipyard Co., respectively, all in Amsterdam.

DUCTILITY RELATED TO SERVICE PERFORMANCE OF HEAVY-WALL AUSTENITIC PIPE WELDS

Authors show important role which ductility plays in the fabrication and service performance of welds in heavy-wall austenitic-steel piping and particularly as related to high-temperature central station service

BY HENRY M. SOLDAN AND CHARLES R. MAYNE

ABSTRACT. In this discussion the authors correlate the results of the newly developed Rensselaer Polytechnic Institute hot-ductility tests with the fabrication and service performance of austenitic-steel piping in high-temperature central station service, and foresee that these tests, performed on initial ingots or blooms, may eventually become a part of applicable piping material specifications. They show that, in the meantime, welds in highly restrained thick-wall piping, which have been difficult to make because of poor hot ductility of the base metal, have been successfully made with the new 16Cr – 8Ni – 2Mo electrodes, which fact they attribute to the relief of residual welding stresses by the higher ductility of this weld metal. No reasons are set forth as to the cause of the occasional cracking failures which have occurred. An outline is given of the work contemplated for the solution of this problem.

Introduction

The purpose of this paper is to show the important role which ductility plays in the fabrication and service performance of welds in heavy-wall austenitic-steel piping and particularly as related to high-temperature central station service.

When heated or cooled, all metals expand or contract. If this expansion or contraction is restricted, then the heated or cooled metal is subjected to stress. When the yield point of the metal is exceeded, permanent deformation will occur. Failure may occur following excessive plastic flow or by stress to rupture. During fabrication by welding, the metal is subjected to varying temperatures up to and down from the melting temperatures. While one portion of the weld zone is being heated, another part may be cooling from the melting temperature. It can easily be seen that only a ductile material could be expected to be welded without any cracking having occurred.

Thermal expansion stresses are also imposed during service at elevated temperatures. The stresses occurring from differential thermal conditions are magnified when the metal involved has a low heat-conductivity coefficient, such as have the chromium-nickel austenitic stainless steels. The section thickness also influences the imposed stresses which become greater as the thickness increases.

In 1951 Mochel [14] ran a test to determine the shrinkage in a heavy wall ($12^3/_4$-in. OD by $2^1/_8$-in. wall), Type 347 austenitic weld (Fig. 1). This test indicated that the compressive stresses in the lower part of the weld reached a considerable magnitude and that the tension stresses at the outer surface approximated the yield strength of the material, as evidenced by the amounts of shrinkage shown.

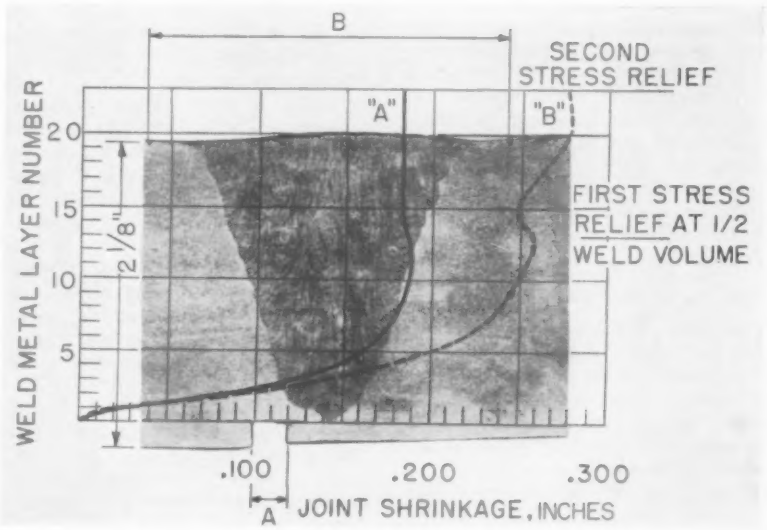


Fig. 1 Weld shrinkage test (backing ring is integral)

To date the requirements for both welding procedure and operator qualification for high-temperature weldments have been that the specimens meet the various room-temperature tests prescribed in the ASME Boiler Code, the relationship between the ductility of the deposited weld and base metal at present being defined only by certain "essential variables" which have proved to be inadequate to assure satisfactory

Henry M. Soldan is Senior Engineer, Electric Engineering Department, Public Service Electric and Gas Co., Newark, N. J., and **Charles R. Mayne** is Metallurgist, Development and Research Division, International Nickel Co., New York, N. Y.

Presented at the Sixth Annual Meeting, AEC Welding Committee, Oak Ridge, Tenn., September 1956.

service performance of austenitic welds in high-temperature service. For example, when a tensile specimen, containing a weld at its middle, broke outside of the weld, the test was considered highly satisfactory since it established the fact that the weld was stronger than the base metal. The effect of the stronger cast weld metal upon the adjacent base metal was not considered.

As we now look back, it becomes apparent that this qualifying test did not adequately predict the suitability of welded joints for heavy wall Type 347 piping for the power industry. It seems probable that, in many cases, in obtaining the above results, we imposed stresses in the adjacent base metal weld heat-affected zones reaching proportions approaching the yield point which, for other than ferritic steels in operation at lower temperatures, might result in failure unless the joint had sufficient capability to flow and contract in cross-sectional area during solidification or heat treatment.

AISI Type 347, 18Cr – 8Ni-Cb austenitic stainless steel, because of its good creep and stress rupture properties coupled with comparative freedom from intergranular carbide precipitation, was the original choice of the chromium-nickel series for use, in heavy-wall piping, for power generation. It has remained the popular choice and thus experience on the use of stainless steel in this field is practically limited to Type 347.

Cracking Difficulties

Attention has been focused on this material because of the failure of some of the welded joints. From the amount of publicity given to the failures, one might assume that all welded joints in heavy-wall Type 347 stainless-steel pipe had failed or were on the verge of failure. However, the facts are that there have been failures in only a small percentage of these welded joints. Some cracks have been discovered during the welding operation and others after service. These cracks have been primarily confined to the base metal very close to the weld.

In our examination[10] of base metal weld heat-affected zone cracking, in austenitic welds, both after initial fabrication and following service, it has been observed that most of the cracking, when found, lies in the outer third of the pipe wall which is stressed in tension (Fig. 2). The cracking usually appears to have started at the outer surface and progressed in a plane normal to the pipe wall. The cracking appears to follow grain boundaries. The considerable time at temperature required for these cracks to propagate through the pipe wall under the reversal of stresses occasioned in a high-temperature piping system, and result in a leak,

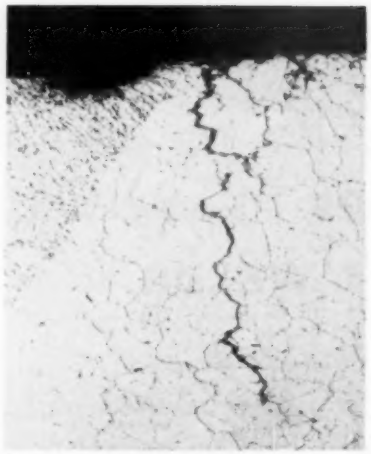


Fig. 2 Weld heat-affected zone cracking. X 100

probably accounts for the fact that no catastrophic failures have occurred in service.

Repairs to cracks found in the base metal weld heat-affected zones at the outer surface of austenitic piping have frequently been difficult to make and progressive cracking further back and into base metal has often resulted as repairs were attempted. In an effort to fill in the repair grooves with a more ductile material, experimental repairs have been made successfully with Type 308 electrodes which are not subject to the effects of stabilizing agents, such as columbium and titanium. Present Boiler Code prescribed stress levels are not conducive to the use of Type 308 for complete pipe-line welds without employing excessive heavy-wall thicknesses.

Many reasons have been advanced, by those interested in the problem, as to the cause of cracking in the base metal weld heat-affected zones in austenitic stainless steels. During the past two years, an EEI-ASTM-ASME Joint Committee SP-5 has been investigating the subject. For further discussion on this phase, the reader is referred, among others, to the papers presented by Heuschkel,[4] Puzak,[2] Wiley[3] and Carpenter,[11] most of which have been published in the *Welding Research Supplement*. At the moment, the theoretical aspect remains unsolved; but from a practical point of view, we feel that much progress has been made, as evidenced by the results of the new hot-ductility tests, later described, conducted at Rensselaer Polytechnic Institute.[1]

Welding Electrodes

In the Spring of 1955, there became available a new 16Cr – 8Ni – 2Mo electrode.[9] This electrode was developed after a considerable study of the factors involved, not the least of which was that the weld metal have sufficient ductility to absorb the stresses resulting from welding without imposing more stress upon the adjacent base metal weld heat-affected zone, before it had cooled down, than it was able to take, particularly if the material was hot short, or if notches were present due to sudden change in cross section, or if in the connection considerable restraint were present due to improper design conditions.

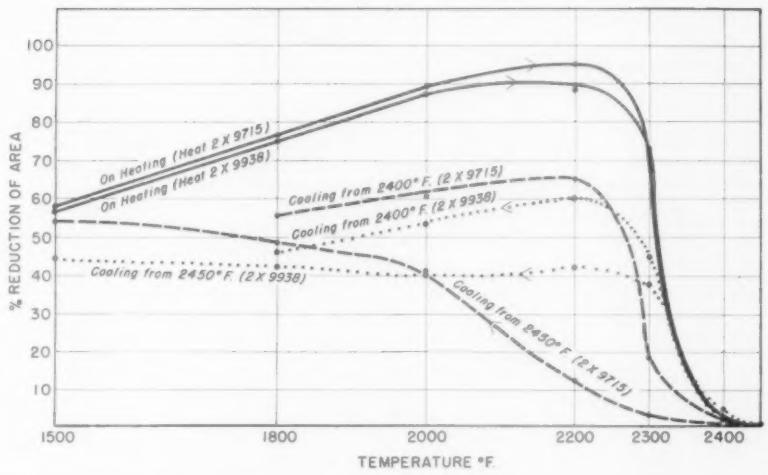
In general, the established grades of the AISI 300 Type Series, such as 316, 321 and 347, were developed for the chemical industry, the latter two largely to avoid chromium depletion in the weld heat-affected zones which had resulted in the so-called "intercrystalline embrittlement" when welded piping was employed in certain chemical processes. None of these steels were actually developed for high-temperature steam piping. The first alloy specifically designed for this service was the new 16-8-2. While this material, so far, has only been used for welding electrodes, large heavy-wall pipe sections have been made satisfactorily and are currently being installed for test purposes. No stress values have as yet been assigned for this material in the ASME Boiler Code, but tests indicate that its properties are comparable with Type 347.

Numerous tests and service applications by the authors and others appear to have verified the fact that a relatively ductile weld deposit, such as that resulting from the use of the 16-8-2 electrodes, have made possible the making of new, as well as repair welds, without base metal weld heat-affected zone cracking in some pieces of Type 347 austenitic steel piping which had proved to be crack sensitive when welded with the best of the controlled low-ferrite electrodes, which had come to our attention.

One specific case, which is typical of many others and which brings out the advantages to be gained by the use of more ductile austenitic welding electrodes is cited. In making up Type 347 heavy-wall piping connections $10^{1}/_{2}$-in. OD by $1^{5}/_{8}$-in. wall between the throttle valves and the steam chests of a large central station unit, three of the welds were readily made with controlled low-ferrite Type 347 electrodes and solution heat treated without requiring any repairs, while three other similar weldments caused considerable trouble and delay due to cracking in the base metal weld heat-affected zone. The latter three welds were then remade using the new 16-8-2 electrodes without any cracking difficulty whatsoever.

Some authorities recommend that shop welds employing 16-8-2 be solution heat treated if the entire piece is required to go into the furnace but are doubtful of the over-all benefits to be

Fig. 3 The effect of heating on the ductility of two heats of Type 347 →


% REDUCTION OF AREA
TEMPERATURE °F
On Heating (Heat 2 X 9715)
On Heating (Heat 2 X 9938)
Cooling from 2400° F. (2 X 9715)
Cooling from 2400° F. (2 X 9938)
Cooling from 2450° F. (2 X 9938)
Cooling from 2450° F. (2 X 9715)

derived from local heat treatment. We have not solution-heat-treated field welds employing 16-8-2 electrodes, as it is believed that this practice is not essential to inhibit the formation of sigma, which frequently results if welds made with ferrite-bearing Type 347 electrodes are not solution heat treated.

Hot-Ductility Tests

Studies have been conducted on the properties of Type 347 and other stainless steels to determine the effect of temperatures approaching the melting point on the properties of the alloys. These tests have been conducted on apparatus developed at Rensselaer Polytechnic Institute[7] with the cooperation of the General Electric Co. and Oak Ridge National Laboratories.

This equipment permits the heating and cooling of specimens at rates approximating those incurred during welding. Briefly, specimens can be heated to any desired peak temperature and cooled to any predetermined temperature and broken at this or any desired point in the cycle. The highest peak temperature usually employed is 2400 or 2450° F although 2500° F has been used in some tests. The reduction of area is measured as an index of the hot ductility of the specimen.

Figure 3 shows the results obtained on two heats of Type 347 stainless steel which show differences in ductility after heating to 2400 and 2450° F. It will be noted that on heating there is practically no difference in the ductility of the two heats. Both show that ductility increases up to between 2200 and 2300° F, and at 2400° F their ductilities have been reduced to a very low value. These low values persist at 2450° F. When heat 2×9938 is cooled to 2300° F from 2400° F, it regains much of its ductility, whereas heat 2×9715 regains a much lower portion. In cooling from 2450° F, the difference between the two is much more noticeable. Heat 2×9938 regains a good degree of ductility when the temperature is lowered to 2300° F and lower. The ductility of heat 2 × 9715 remains below 10% (reduction in area) down to almost 2200° F. When the stresses which are imposed in cooling from 2450° F are considered, one can readily conclude that heat 2×9715 would have a greater tendency for cracking during welding than heat 2 × 9938.

We have tested unstabilized stainless steels of the 300 Series without finding one that does not regain its ductility

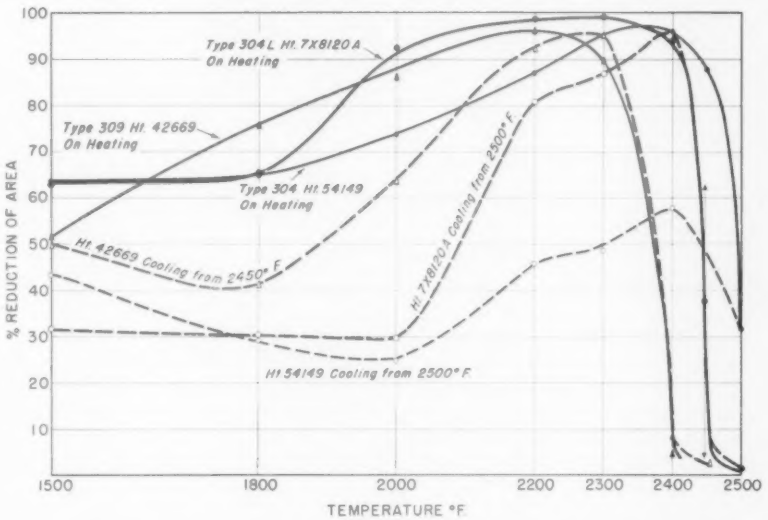

% REDUCTION OF AREA
TEMPERATURE °F
Type 304L Ht. 7X8120A On Heating
Type 309 Ht. 42669 On Heating
Type 304 Ht. 54149 On Heating
Ht. 42669 Cooling from 2450° F.
Ht. 7X8120A Cooling from 2300° F.
Ht. 54149 Cooling from 2500° F.

Fig. 4 The effect of heating on the ductility of types 304, 304L and 309

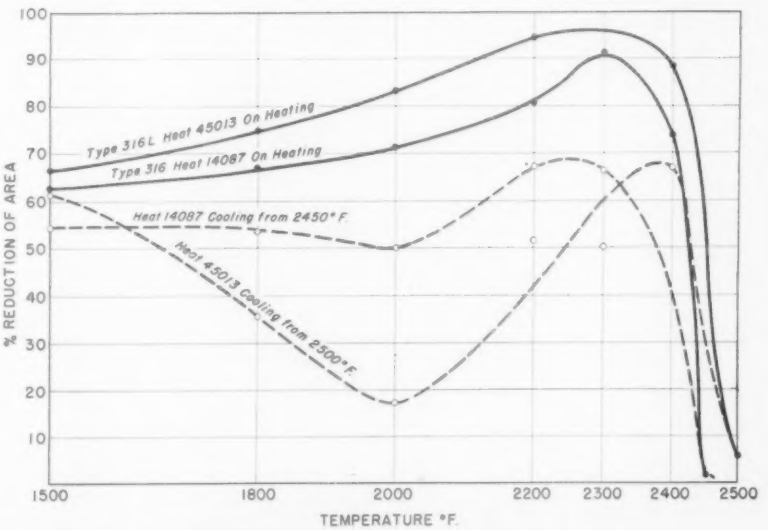

% REDUCTION OF AREA
TEMPERATURE °F
Type 316L Heat 45013 On Heating
Type 316 Heat 14087 On Heating
Heat 14087 Cooling from 2450° F.
Heat 45013 Cooling from 2500° F.

Fig. 5 The effect of heating on the ductility of types 316 and 316L

Table 1—Service Material Tested

Item no.	*Sample no.*	*Material*	*Kind†*	*Size, in.*	*Service, hr*	*Performance*	*Reduction of area % in hot-ductility test*
1	A	347	Wrought pipe	6⅝ x 0.718 wall	22,720 at 1050° F	Good	72
2	B	347	Wrought pipe	6⅝ x 0.718 wall	11,850 at 1050° F	Broke in service	13
3	S16	347	Forged valve	12 x 2¼ wall	9,170 at 1050° F	Broke in service*	19
4	B11	347	Wrought pipe	10½ x 1.580 wall	7,000 at 1100° F	Good‡	59.3
5	K9	347	Forged pipe	9¾ x 1⅝ wall	26,000 at 1100° F	Varies‡, §	39.3
6	S42	347	Forging	7 x 1⅛	41,000 at 1050° F	Crack sensitive, varies	10.2
7	S34	321	Wrought pipe	6⅝ x 0.718 wall	20,000 at 1050° F	Crack sensitive	23.2‖

* Considerable trouble also in initial fabrication.
† All material in accordance with ASTM specifications and supplementary requirements.
‡ Items 4 and 5 taken from test rings of pipe in service.
§ Good at circumferential welds, crack sensitive at support lugs.
‖ Specimens broken at 2300° F upon being cooled from 2400° F, except No. 7 cooled from 2450° F.

rapidly when cooled from the peak temperature. Figures 4 and 5 show the results obtained on individual heats of Types 304, 304L, 309, 316 and 316L. It can be seen that in all of these there is a rapid regain in ductility when the temperature is lowered from the peak temperature. These data should not be interpreted as meaning that Type 347 is the only austenitic stainless steel which has a low rate of regaining ductility when cooled from elevated temperatures. The reason for this low ductility has not been established and until this has been accomplished or until many more tests have been made on other Cr-Ni austenitic stainless steels, it would be wrong to conclude that only Type 347 has a low rate of regaining ductility when cooled from temperatures approaching the melting point. However, the authors feel that the stabilized stainless steels and particularly Type 347 are more susceptible to cracking during the welding of heavy sections than the unstabilized stainless steels.

Several materials which have been in service at various generating stations of Public Service Gas and Electric Co. of New Jersey were tested, under the sponsorship of the International Nickel Co., to determine whether or not the hot-ductility tests would coincide with service performance. These materials are listed in Table 1. The results of the testing of these materials are shown in Fig. 6 and 7. It will be observed that the curves are not as complete as the previous ones. This is because there were not enough specimens available. It is evident that Samples A and B-11 behave quite similar to heat 2×9938 the better of the two in Fig. 3, and Table 1 shows that these did not crack during fabrication or service. Samples B, S-16 and S-34 behave similar to heat 2×9715 of Fig. 3. Table 1 shows that cracking was encountered in these materials. Figure 8 shows the results of hot ductility tests on the 16-8-2 material, both wrought and weld metal. When compared with the satisfactory weld performance of 16-8-2, the results are consistent. Accordingly, it is logical to predict that the hot-ductility test of Rensselaer Polytechnic Institute may

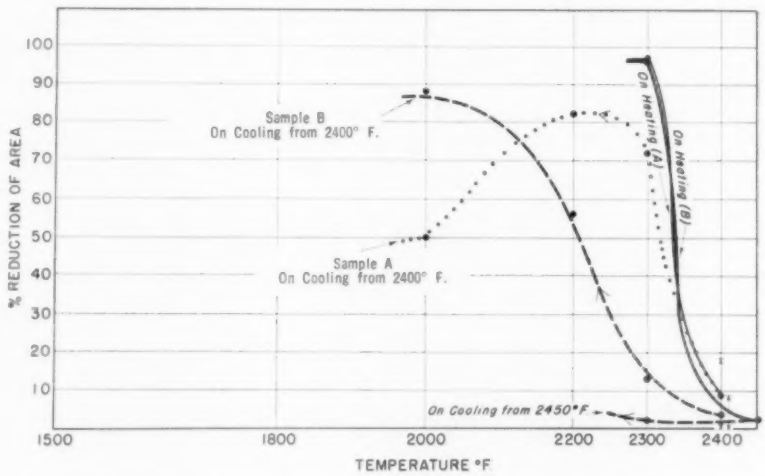


Fig. 6 The effect of heating on the ductility of two Type 347 materials, samples A and B, see Table 1

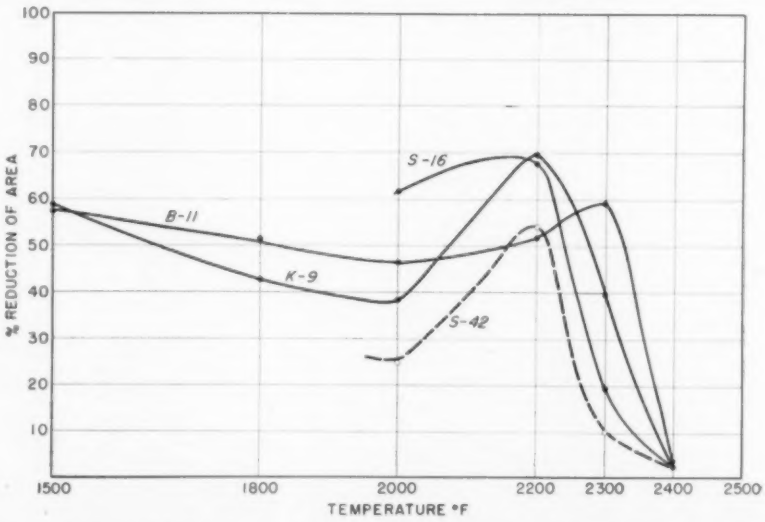
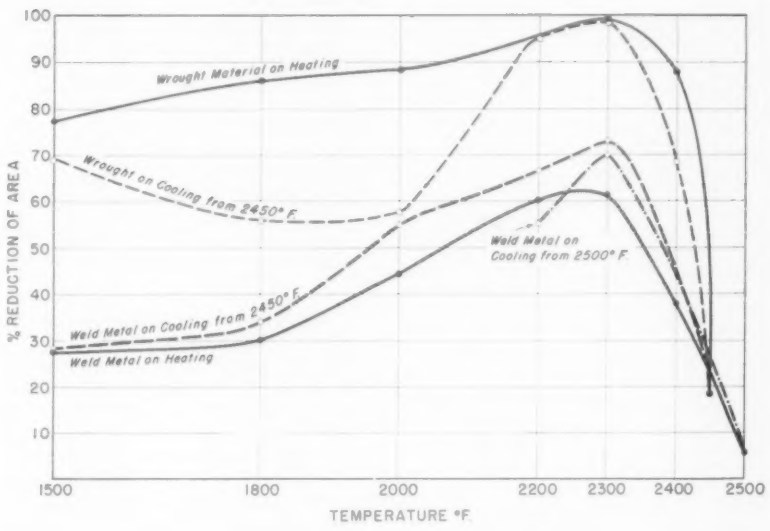


Fig. 7 Effect of heating on the ductility of four Type 347 stainless steels during cooling from 2400° F

Fig. 8 The effect of heating on the ductility of 16-8-2, weld metal and wrought →


% REDUCTION OF AREA
TEMPERATURE °F
Wrought Material on Heating
Wrought on Cooling from 2450° F.
Weld Metal on Cooling from 2500° F.
Weld Metal on Cooling from 2450° F.
Weld Metal on Heating

indicate the tendency of materials to crack during welding. Figure 9 shows a diagram of the range of the reduction of area during the hot-ductility tests for the materials considered for high temperature service.

Base Materials

In 1955, in effort to improve service performance by avoiding cracking difficulties at austenitic weldments, a group representing the metallurgical engineering staffs of nickel and steel producers, turbine and boiler manufacturers and pipe fabricators associated with Public Service was brought together. The results of these discussions indicated that the best choice, at this time, for heavy-wall high-temperature steam piping was AISI Type 316, 16Cr – 13Ni – 3Mo. This material appears to have good high-temperature characteristics and behaves better in the hot-ductility tests. It is currently considered to be a stronger material for high-temperature service than others in the 300 Series and is so accredited in the ASME Boiler Code, in spite of the fact that many authorities believe that the entire series should be reinvestigated on the basis of more complete information as to the effects of heat treatment and grain-size control. Type 308, while appearing suitable from a ductility standpoint, is legislated against by the lower allowable "S" values appearing in the Boiler Code.

While, as before mentioned, the vast majority of welds which have been made in Type 347 austenitic steel piping now in high-temperature steam service has been entirely satisfactory, the erratic behavior of this alloy in the hot-ductility tests is indicative of the same performance in both welding and service, when a poor grade of this material is encountered.

Metallurgical Examination

The results of the laboratory work which we have so far carried out follow: It has been noted that the specimens exhibiting poor ductility (even the good ones at elevated temperatures) failed intergranularly, which is not unexpected for brittle failure. Consideration is being given to the possibility that the brittle failure is probably due to the formation of some intergranular compound. Additional work is under way using the electron microscope, X-ray diffraction and similar apparatus to determine whether or not differences may be found in the grain boundary constituents of these materials.

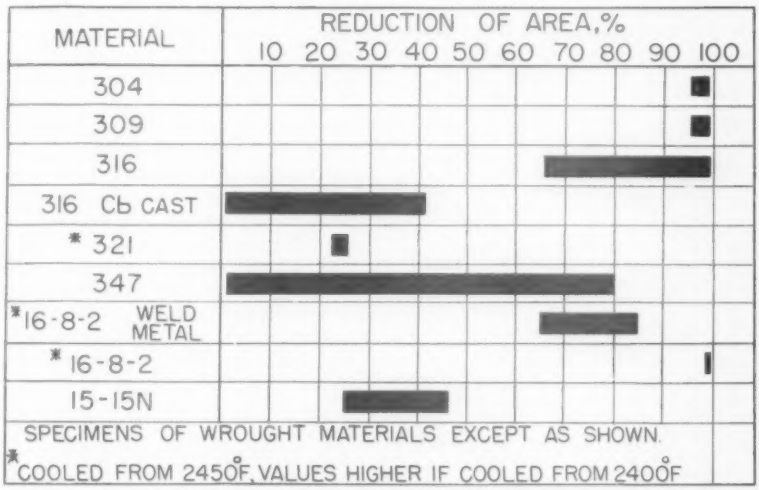


Fig. 9 Range of reduction of area as an index of hot ductility. Samples broken at 2300° F upon cooling from 2400° F

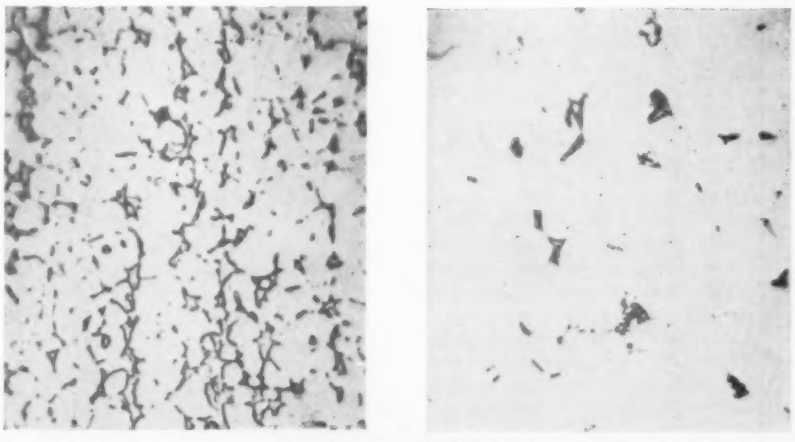


Fig. 10 Structure of heats 2X9938 and 2X9715 after heating to 2450° F and broken. Area approximately 0.020 in. from break. X 500

Table 3—Chemical Analysis of Stainless Steels (Tested for Hot Ductility)

Heat no.	Type	Code no.[1]	C	Ni	Cr	Mo	Cb	Si	Mn	N	P	S	Al	Ti	Sb
2X9715	347	P (Bad)	0.06	12.33	20.09		0.78	...	...	0.024	...	...	0.018	0.14	0.022
2X9938	347	O (Good)	0.06	9.79	20.14		0.82	...	...	0.009	...	...	<0.01	0.14	0.021
Sample A	347	Y (Good)	0.052	12.82	...		0.82	0.54	1.64	0.020	0.007	0.007	0.025	0.053	0.003
Sample B	347	Z (Bad)	0.06	12.84	...		0.83	0.54	1.64	0.027	0.007	0.006	0.033	0.037	0.007

Spectrographic survey

Heat no.	Type	Code no.[1]	B	Ca	Mg	Cu	Pb	Mo	V	Zn	Zr	Li	Sb	As	Ba	Be	Bi	Cd	Ce	W	La
2X9715	347	P (Bad)	VST	ST	ST	T	NF	T	ST	VST	ST	NF	NF	NF	VST	NF	NF	NF	VST	ST	NF
2X9938	347	O (Good)	VST	ST	ST	T	NF	T	ST	VST	ST	NF	NF	NF	VST	NF	NF	NF	VST	ST	NF
Sample A	347	Y (Good)	VST	ST	ST	ST	NF	T	ST	ST	ST	NF	NF	NF	VST	NF	NF	NF	ST	ST	NF
Sample B	347	Z (Bad)	VST	ST	ST	ST	NF	T	ST	VST	ST	NF	NF	NF	VST	NF	NF	NF	VST	ST	NF

T = trace ST = slight trace NF = not found.

Table 2—Magne-Gage Readings on Material Tested for Hot Ductility

Treatment	Material: 2× 9938	2× 9715	A	B
Heated to 2300° F	13	0	0	0
Heated to 2400° F	23	1	0	0
Cooled to 2300° F	31	3	0	0
Cooled to 2200° F	33	0	0	0
Cooled to 2000° F	42	0.5	0	0

Only a limited amount of metallurgical work has been completed at this time. Figure 10 shows the structure of heats 2×9715 and 2×9938 after heating to 2400° F and cooling to 2300° F. It can be seen that heat 2 × 9938 contains considerable amounts of ferrite while 2 × 9715 contains practically none. This is also shown by the magne-gage readings which are included in Table 2 for several heating conditions. This might be interpreted as meaning ferrite is necessary in the base metal to insure freedom from cracking during the welding of heavy sections. However, Fig. 11 shows a comparison of the structure of samples A and B when tested at 2400° F. It will be noted that in neither of these is there any appreciable amount of ferrite present. Since the difference between the behavior of A and B is quite similar to the difference between 2×9938 and 2 × 9715, it would seem that ferrite cannot be the cause of the difference in behavior during welding.

These four materials have been analyzed for differences in chemical constituents. The results are shown in Table 3. It can be seen from this analysis that the cause of the ferrite in heat 2×9938 is due primarily to the lower nickel content. It can also be seen that there is practically no difference at all in the trace elements.

Correlation with Service

If correlation of service performance with the hot-ductility tests on the same material is confirmed after more complete data are obtained, the next problem would be how to procure material with hot-ductility properties which would be suitable for satisfactory weldability and service performance. Obviously, the mills at this time would be reluctant to reject finished tubes because of low hot ductility. This means that this property must be determined early in the production stage and preferably on specimens taken from the initial ingots or blooms. We do not know as yet if the hot ductility values remain consistent throughout the manufacturing process and, to obtain data on this, we have secured several samples representing various stages of the manufacture of AISI Type 316 piping intended for the main steam piping at No. 2 Unit, Linden Generating Station. We expect, if further data on this and other types prove consistent, to propose a revision to ASTM Specification A376, for high-temperature austenitic piping, which will require that the material meet certain hot-ductility test requirements. For example, "the reduction of area of a specimen of the ingot from which the piping will be made shall show a reduction of area of not less than (x) percent when broken at (x) F upon cooling from (x) F."

The Rensselaer tests indicate that in many cases the reduction in area may be considerably lower when specimens are broken at 2300° F upon cooling from 2450° F than upon cooling from 2400° F. The cause of this phenomenon is not clearly understood. Examination of the data so far obtained indicates that the susceptibility to cracking can be evaluated by considering the ductility at 2300° F upon cooling from 2400° F. Values of reduction of area

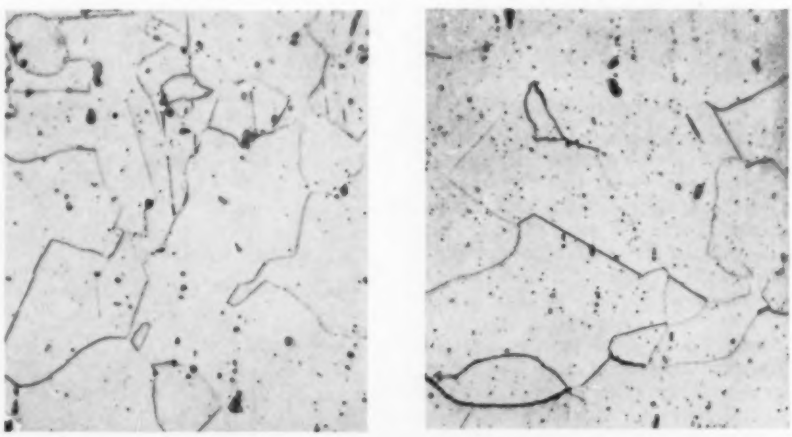


Fig. 11 Structure of materials A and B. Heated to 2400° F and broken. Area approximately 0.020 in. from break. X 250

of 60% and over appear indicative of satisfactory service performance. After more data have been established, comparisons may take into consideration the variation in peak temperatures, for the several types, at which the reduction in area approaches zero.

In our examination of the hot-ductility test data, we have found that the reduction of area in transverse specimens, taken from narrow test rings, was in certain instances lower than in longitudinal specimens taken from longer sections. We believe that this could account for the variable performance indicated for Item 5 in Table 1, the tests of which were made on transverse specimens, and in which the butt welds have given excellent performance while support lug attachments have invariably caused severe cracking of the heavy-wall piping. This leads us to conclude that the safest practice is to avoid the use of welded support lugs unless sufficient flexibility is provided in the design to permit the free expansion of all parts.

There is no indication that a material displaying good hot ductility during initial fabrication will depreciate in this respect, in service, as evidenced for example by sample A, Table 1, which had 72% reduction of area after 23,000 hr of service at 1050° F.

Further Studies

It is planned to obtain additional material from sections of piping with known crack sensitivity and poor service performance as soon as these materials are replaced in service. It is hoped that this information will support the limited data now available and that the hot-ductility tests will aid in the selection of suitable materials for high-temperature service. Other utilities and associated companies are encouraged to obtain material representing the various heats of main steam pipe from which hot-ductility tests can be made and compared with their actual service performance.

Also under consideration are the effects of the following variables:

Grain size on which a limited amount of work has been done.

Melting practice. In this connection, when sufficient amounts of a poor material become available, some of this will be remelted in vacuum to determine whether or not this will remove the cause of crack sensitivity.

Forging Practice. In the event that a heat shows poor ductility in the ingot, it is proposed that the effect of variable amounts of forging should be investigated to determine how much hot work is necessary to remove or reduce sensitivity to cracking as a result of welding.

Chemistry. In this connection, it is planned to study the effect not only of minor elements such as nitrogen but also the effect of the ratio between carbon and stabilizing elements.

It is expected that a large portion of this work will be sponsored by the International Nickel Co. working in close contact with the EEI-ASTM-ASME Task Force SP-5, which is currently investigating this subject.

While the hot-ductility test may separate the good from the bad, and while the use of 16-8-2 welding rod may facilitate the welding of at least some of the crack-sensitive material, the paramount question still remains, "Why are some heats of austenitic stainless steel sensitive to cracking while others of similar composition are insensitive to the same type of failure under identical conditions?"

Summary

The data on the hot-ductility tests are limited at this time, but the authors believe that they are sufficient to indicate a trend which can aid in the selection of suitable heavy-wall austenitic pipe for high-temperature service. They are certain that ductility plays a very important role in the successful service performance of austenitic weldments as reflected by the successful use of more ductile electrodes such as the new 16-8-2. They suggest that careful consideration be given to these details.

Acknowledgments

The authors wish to express their appreciation to F. P. Fairchild, Chief Engineer, Electric Engineering Department, Public Service Electric and Gas Co.; and Dr. V. N. Krivobok, Head, Stainless Steel and Heat Resisting Alloy Section, International Nickel Co., for their guidance in this work.

References

1. Nippes, E. F., Savage, W. F., and Grotke, G., "Further Studies of the Hot Ductility of High Temperature Alloys," report Rensselaer Polytechnic Institute, June 1956.
2. Puzak, P. P., Apblett, W. R., and Pellini, W. S., "Hot Cracking of Stainless Steel Weldments," THE WELDING JOURNAL, 35 (1), Research Suppl., 9-s to 17-s (1956).
3. Carpenter, O. R., and Wylie, R. D., "Some Considerations in the Welding of Austenitic Chrome-Nickel Stainless Steels," AWS and ASME Metals Engineering Division Conference, May 1956.
4. Heuschkel, J., "Time and Temperature Dependence of Austenitic Stainless Steel Welded Joint Components," *Ibid.*
5. Nippes, E. F., Fleischman, W. L., and Schaaf, B., "Time-Temperature Effect on Properties of Weld Heat Affected Zones in Type 347 Stainless Steel," *Ibid.*
6. Heuschkel, J., "Initial Characteristics of Chromium-Nickel Steel Weld Metals," THE WELDING JOURNAL, 34 (10), Research Suppl., 484-s to 504-s (1955).
7. Nippes, E. F., Savage, W. F., Bastian, Mason, H. F., and Curran, R. M., Investigation of the Hot Ductility of High-Temperature Alloys," THE WELDING JOURNAL, 34 (4), Research Suppl., 183-s to 196-s (1955).
8. Nippes, E. F., Wawrousek, H., and Fleischman, W. L., "The Heat-Affected Zone in Arc-Welded Type 347 Stainless Steels," *Ibid.*, 34 (4), Research Suppl., 169-s to 179-s (1955).
9. Carpenter, O. R., and Wylie, R. D., "Mechanical Properties of 16-8-2 Weld Deposits as Compared with 19-9 Cb.", private report, April 1955.
10. Soldan, H. M., "Welding and Inspection Techniques for High Temperature-Pressure Central Station Piping," Pennsylvania Electric Assn., February 1955.
11. Carpenter, O. R., and Wylie, R. D., "The Importance of Weld Composition and Hot Ductility with Respect to Austenitic Weld Cracking," presented at AEC Welding Committee Meeting, September 1955.
12. Weisberg, H., and Soldan, H. M., "Cyclic Heating Test of Main Steam Piping Materials and Welds," *Trans. ASME* Vol. 76, No 7 (October 1954).
13. Poole L. K., "The Incidence of Cracking in Welding Type 347 Steels," THE WELDING JOURNAL, 32 (8), Research Suppl., 403-s to 412-s (1953).
14. Mochel, N. L., and Pratt, J. A., "Shrinkage Encountered in Making Heavy Butt Welds in Forged Austenitic Steel Pipe," private report, Novebmer 1951.

DISCUSSION BY R. M. CURRAN AND A. W. RANKIN

The authors are to be congratulated on their excellent discussion of the problems associated with the use of the austenitic steels in steam power piping and of the test programs they are conducting to aid in providing solutions to these problems. Mr. Soldan, in particular, is to be commended for his constant efforts in championing the cause of the austenitic steels for this service and in providing inspiration for many of the development programs concerned with improving the reliability of austenitic piping currently under way.

As the authors have pointed out, there appears to be a good correlation between the results of the RPI hot-ductility test and the tendency toward cracking during welding in the austenitic steels. Since this test simulates the thermal cycle to which base metals are subjected during the welding process, and provides a means of determining ductility during the cycle, it is difficult to imagine a more representative test to determine this aspect of "weldability." The discussers' company provided the initial financial support and direction in 1952 to the modifications of the RPI equipment necessary to conduct this test, and have now installed similar equipment in our own laboratories. We intend to use this equipment not only as a means of checking production materi-

R. M. Curran is Supervisor, Turbine Materials Engineering, and **A. W. Rankin** is Supervisor, Turbine Structural Engineering, Large Steam Turbine-Generator Department, Schenectady, N. Y.

als prior to shop fabrication, but also as a research tool in an endeavor to determine the basic factors which determine the "hot ductility" of the austenitic steels and superalloys.

The authors have attributed the superior performance of the 16–8–2 electrode in welding materials with poor hot ductility to the superior ductility of this electrode. In the discussers' opinion, however, the lower yield strength of the 16–8–2 electrode at the temperatures at which base materials exhibit low ductility is more responsible for its lesser tendency to cause cracking in the base metal. In other words, it would appear more important that when the weld metal contracts on cooling, that the strain associated with this contraction occurs in the weld metal rather than in the low ductility heat-affected zone. The ductility of the 16–8–2 weld metal is undoubtedly important in determining the resistance to cracking in the weld metal itself.

Since the reason for the cracking which has been encountered adjacent to welds in service has not been completely explained, and there is considerable disagreement on the various mechanisms proposed, the relative roles of the "hot ductility test" and the 16–8–2 electrodes have not been well defined. The discussers look forward to additional data correlating hot ductility tests with service performance as reported by the authors and to service performance data on the many 16–8–2 welds now in service to which no postweld heat treatment has been applied. There is no question that the tendency toward cracking in service varies markedly from one heat of steel to another and that for a given heat of steel, welds made with the 16–8–2 electrode with no postweld heat treatment are less prone to cracking than unheat treated Type 347 welds. At the present state of knowledge, however, the discussers believe that a postweld heat treatment of austenitic welds is still advisable for maximum reliability.

DISCUSSION BY J. D. CONRAD and E. A. FOX

We are sure that all users and manufacturers of welded austenitic structures join us in a vote of thanks to the authors for making their observations and correlations available to us in such well-organized form. Continued effort of this type and dissemination of information will lead to continued rapid advancement in the technology of austenitic welding, particularly in the high-temperature power-piping field.

We agree with Messrs. Soldan and Mayne that hot-ductility requirements should be made a matter of specification for high-temperature austenitic piping if it continues to appear as important as indicated by the data in this paper. It may be of interest that we plan to make hot-ductility tests from material representative, as nearly as practical, of all welding ends on the turbine inlet piping on three high-temperature turbines which we are now building. One of these machines is for Eddystone Station of the Philadelphia Electric Co. and will operate with 5000 psi, 1200° F inlet steam. The other two units will operate with 2350 psi, 1100° F inlet steam at the Bergen County Station of Public Service Electric and Gas Co. Governor valves, throttle valves, weld-ells and U bends will be tested as well as the pipe itself. It is also our intent to make creep-rupture tests from material adjacent to the hot ductility tests so that correlation with strength as well as with fabrication and weldability observations can be made.

With regard to the authors' proposal that hot-ductility requirements be incorporated in the ASTM A-376 specification for high-temperature piping, we wrote such a requirement into our purchasing specifications for the above-mentioned three units. However, due to metal-makers' lack of knowledge of melting and forging factors which affect hot ductility of the product, acceptance of this requirement by our suppliers has not been universal.

The authors' finding of a difference between longitudinal and transverse hot ductility and its possible effect on the integrity of support lug attachment welds is of interest. Although we did not have definite data to support our stand, we have avoided the use of welded support brackets and other welded appendages on our austenitic inlet pipes currently being built.

J. D. Conrad and **E. A. Fox** are associated with Large Turbine Engineering, Westinghouse Electric Corp., Lester, Pa.

DISCUSSION BY H. S. BLUMBERG

The paper by Soldan and Mayne emphasizing the importance of hot ductility is an important contribution to the rapidly increasing knowledge of the high-temperature behavior of austenitic piping materials, because it is the first presentation which relates the results of the recently developed weld-thermal cycle hot-ductility test to actual behavior of steels in steam power plant service. By presenting data on the serious but relatively small degree of cracking in service with heavy-walled Type 347 piping welded with electrodes of generally matching deposit composition, the authors have done much to dispel undue doubts which may have been generated in the minds of users of piping, emanating from generalized statements on the subject. In particular, the encouraging result which they have reported in welding with the 16Cr – 8Ni – 2Mo electrode offers the probability that the control of cracking in fabrication of heavy-walled austenitic weld joints is imminent. Of great significance is the fact that a large number of 16 – 8 – 2 deposits, both as repair welds and used singly in full butt joints, have now been in service for many thousands of hours without any adverse effects yet observed.

The summary review of the recently developed weld-thermal cycle hot ductility test will be especially appreciated by those not thoroughly familiar with the several detailed papers and the laboratory test data reported by the originator of this test technique, Dr. E. A. Nippes, whose work represents an outstanding metallurgical achievement.

One point brought out by the authors, i.e., that "considerable time at temperature in service was required for the cracks to propagate through the pipe wall, which probably accounts for the fact that no catastrophic failures have occurred in service" is of prime impor-

H. S. Blumberg is Consulting Metallurgist, New York City; was formerly Chief Metallurgist, M. W. Kellogg Co., Jersey City, N. J.

tance. This fact is encouraging to the industry in the extension of the use of the currently approved Cr-Ni base austenitic steels and consideration of the newly proposed modifications including the "lean alloy" super strength compositions. The evidence thus far appears to be strong that under steam power plant conditions crack propagation is a cyclic, stress rupture type of phenomenon, requiring considerably more time and higher energy levels than in the brittle type of behavior experienced in many plain low-carbon steels at certain ambient and subzero temperatures. The consequence of the type of behavior reported by Soldan and Mayne is that time is thus available for periodic surface inspections to be made.

The authors certainly ask a pertinent question in, "Why are some heats of austenitic stainless steel sensitive to cracking while others of similar composition are insensitive to the same type of failure under identical conditions?" Their approach to the problem by investigating additional material from sections of piping with known crack sensitivity and poor service performance is most direct and industry awaits the results of these findings.

The authors also state that they have under consideration a study of the effects of the four variables: grain size, melting practice, forging practice and chemical composition including minor elements. These general variables and a number of other subfactors were described broadly in a recent paper by the present discusser given before the 1956 Annual ASME Meeting. An attack of the problem by this method is indeed necessary for a fundamental solution of the problem. The complexity of such investigations is, however, apparent and in this connection, A. W. Rankin of General Electric Co., in discussing the writer's paper, has urged the forming of an industry-wide group with a large technical personnel and sufficient funds to perform the considerable amount of investigation which would be required.

It appears highly probable that the greater part of the solution of the problem will result from study of the effects of variables in the melting operation and the control of chemical composition. Here the background and experience of leading metallurgical engineers representing austenitic stainless steel producers in cooperation with piping converter and fabrication and steam power plant metallurgical personnel would be of great value in setting up a study program. It will be remembered that the graphitization effects encountered by the steam power industry in carbon molybdenum steel were found to be strongly related to melting practice (aluminum deoxidation), with ultimate control resulting from a change in chemical composition, i.e., the addition of chromium. Similarly, it has been shown that brittle behavior of low-carbon steels is related to melting practice and control of composition. It should not be construed from the above that melting practice is believed to be the only factor which should be considered; however, it appears highly probable that the melting operation plays a major role.

Another approach to the problem would be to obtain commercial austenitic steels from a number of producers of these materials, in the United States and abroad, particularly in England and Germany. Results of hot ductility tests on such compositions could be correlated with melting practices of the producers, with the ultimate aim of controlling hot ductility characteristics.

In the steam power industry the behavior of austenitic main steam piping steels is, based on experience to date, essentially a welded joint problem, specifically at the heat-affected zone, which requires focus on the structure and properties of this zone. Since the heat-affected region is nearly always coarse grained, and large grained structures are inherently more prone to hot shortness, a need exists for the development of austenitic steels which are more sluggish to grain coarsening in the very short time periods to which zones in base metal adjacent to the weld metal are subjected in welding. The addition of elements such as cerium, the oxides of which are reported to produce smaller grains in cast materials by providing more nuclei and possibly other grain growth restraining elements, would appear worthy of study.

The company with which the discusser was associated is currently engaged in the fabrication of heavy-walled Type 316 austenitic main steam piping for five modern high-temperature stations for the Public Service Electric and Gas Co. and The Philadelphia Electric Co., with the most severe service conditions represented by the Eddystone Unit 1 of the latter company, i.e., 1200° F. 5600 psi. For all these piping materials data are being collected regarding melting practice, grain size and metallographic structure and, in addition, weld-thermal cycle hot ductility tests on actual production materials used. The results will ultimately be related to behavior of materials in fabrication and service.

Messrs. Soldan and Mayne are to be congratulated for their well-organized paper and their stimulation of others to carry out studies of the behavior of welded joints in heavy-walled high-alloy steels.

DISCUSSION BY R. D. WYLIE

The authors are to be commended for a very interesting analysis of service failures and some of the measures which have been taken by Public Service of New Jersey to both correct the problem and to better define the basic difficulties which have arisen in the welding of Type 347 stainless steels. We have been happy to be associated with the authors in this development program, and have followed it with great interest.

The 16–8–2 material which was mentioned in the report was developed by The Babcock & Wilcox Co. in cooperation with U. S. Navy Bureau of Ships Code 537. The excellent properties of this material described by the authors have correberated many of the thoughts which were used in the development of this material, particularly with reference to importance of ductility of the weld metal. We expect that the final answer to the problem of hot cracking of weldments will not be merely a change of weld deposits. Since the basic problems are apparently associated with Type 347 steels, the obvious conclusion is that a change in wrought material should also be made. For this reason we have developed the 16–8–2 wrought material which was also mentioned in the paper. This material will be subject to many types of tests including the hot ductility test at RPI, the stress relaxation test at General Electric and the creep and stress rupture tests at The Babcock & Wilcox Co. In addition, Mr. Soldan is going to place a section of pipe of this material in a cyclic heating test vessel which they have used for many years at their Sewaren Station. The results of all of these tests should give an indication of whether this material is a substantial improvement over Type 347 or Type 316 for high-temperature, high-pressure steel pipe.

R. D. Wylie is Chief Metallurgist, Quality Control Dept., The Babcock & Wilcox Co., Barberton, Ohio.

AUTHORS' CLOSURE

The opportunity offered by Mr. Wylie's company to install a piece of wrought 16–8–2 pipe in the cyclic heating test being conducted by Public Service Electric and Gas Co. and which is intended to duplicate high-temperature steam service performance, is appreciated. A report on the original test appears in ASME *Transactions*.[12] Based on information obtained on this new material in the current Rensselaer tests, we are most optimistic of the results.

Mr. Conrad's intention to make hot ductility tests on piping materials intended for high-temperature steam service appears to be a step in the right direction. However, the data given in our paper must be confirmed by more conclusive relations between hot ductility and service performance before an acceptable standard for rejections can be determined.

The interest of Mr. Blumberg in this work has been a contributing factor to the progress made so far. Mr. Blumberg suggests that the hot shortness found in certain specimens may be due to the coarse grains in the base metal weld heat-affected zone, in which the majority of the cracking has been found. While coarse grain size has been blamed for many of the difficulties occurring in the fabrication and welding of austenitic steels, we find no evidence to conclude that coarse grain size alone is responsible. It seems likely that some weakness occasioned by the welding and/or chemistry of the base metal, not yet identified as such, which may in some instances occur concurrently when coarse grain size is found, is the factor which promotes the hot shortness observed.

We are in agreement with Messrs. Curran and Rankin in that the lower yield strength of 16–8–2 during the weld deposition contributes to the success of welding with this electrode by, as we said, its capacity to "absorb the stresses resulting from welding without imposing more stress upon the adjacent base metal weld heat-affected zone, before it had cooled down, than it was able to take, particularly if the material was hot short. . . ." We await with interest the test which the discussers intend to make to "determine the basic factors which determine the 'hot ductility' of the austenitic steels. . . ."

The authors appreciate the support evidenced by the various discussions on their paper.

PAPERS AT THE FOURTH CZECHOSLOVAKIAN WELDING CONFERENCE, 1954

ABSTRACTED BY G. E. CLAUSSEN

VOL. 1. *Paper No. 1.* "Weldability Tests," by J. Cabelka. The properties of mild steel related to brittleness are injured by the rapid heating and cooling cycle of welding. Steels that tend to age are susceptible to damage by welding, whereas nonaging steels are not. The Charpy keyhole test is used to evaluate the toughness of zones in and adjacent to welds. The specimens are tested at room temperature. Rimmed steel in this test often exhibits impact values as low as 3 mkg/cm², whereas killed steels show little loss of toughness in the heat-affected zone.

Paper No. 2. "Generator and Transformer Characteristics for Arc Welding," by V. P. Nikitin. The two forms of controlling automatic arc welding by self-regulation at constant wire feed rate and by voltage regulation are described. Consideration of different systems for alternating current shows that the best has a common core for the secondary and inductive windings. This system is economical of material and manufacturing time. Transformers of this type are used throughout Russia for manual and automatic welding.

Paper No. 3. "Wear Resistant Surfacing Alloys for High Temperature Service," by J. Nemec. The basic factors controlling the wear of high-pressure steam valve disks are the temperature and the specific pressure on the wearing surfaces. A $^{3}/_{16}$-in. rod of the material to be tested was rotated between two other rods of the same material under pressure. The frictional moment was measured during test, and the cylinders were examined for wear after test. The temperature was 1040° F. The stellite alloys were best with the Ni-Cr-W-V alloys next. These contained 1.5 C, 15 Cr and either 25 W, 0.5 V or 20 W, 1.5 V, the remainder being nickel. Dilatometric and elevated-temperature hardness tests also indicated that the Ni-Cr-W-V alloys were similar to stellite and superior to iron-chromium alloys and Cr-Ni steels.

Paper No. 4. "New Methods of Studying the Effect of Alloying Elements on the Properties of Metals," by V. Koselev. Atomic relationships are correlated to determine the speed of martensite and carbide formation in alloy steels during cooling after welding.

Paper No. 5. "Trends in Welding Development in Poland," by J. Pilarczyk. Welding began to develop in Poland only after World War II. A welding institute was founded at Gliwice but only started work on its first research problem in 1950. Three technical schools commenced degree courses in welding at that time. In recent years the Institute has worked on the building up of high-speed steel tools by welding, on repair welding, on new types of electrodes for special purposes, etc.

Paper No. 6. "Welding and Powder Metallurgy," by C. Agte and L. Jenicek. There are two contacts between welding and powder metallurgy. (1) The use of the products of powder metallurgy in welding. Sintered tungsten compositions are used for spot

(*Continued on page 168-s*)

Abstract of "Zváračský Sbornfk," three volumes. Vydavatelstvo Slovenskej Akadémie Vied, Bratislava, Czechoslovakia, 1955.

G. E. Claussen is associated with the Development Laboratories, Linde Air Products Co., Newark, N. J.

FUNDAMENTAL CONCEPTS OF OXYGEN CUTTING

Chemistry of the iron-oxygen system is shown to be the significant factor that permits iron to be oxygen cut

BY R. L. STOECKER AND W. B. MOEN

ABSTRACT. Although the performance of oxygen cutting and related processes is well documented, there is a dearth of information specifically related to the reasons for the ability of an oxygen jet to cut ferrous metals. It is believed that the chemistry and kinetics of the reaction, the gas dynamics of the oxygen stream and various heat transfer mechanisms interdependently control metal removal by an oxygen jet. Presented in this paper is a discussion of these factors with a report of experimental investigations.

Introduction

The increased utility of oxygen as a tool for processing ferrous metals has been made possible by the continual development of better equipment and techniques by equipment manufacturers and consumers. These improvements have been the result of demands made by the metal working industry for higher production rates and improved product quality. Most of the improvements, however, have been the result of empirical advances while little has been gained toward an understanding of the fundamentals of the process. It is believed that any further significant improvements must be derived from a basic study of the factors that influence the process.

It is the purpose of this paper to delineate the interdependent phenomena that permit iron to react with an oxygen stream. Although, many oxygen metal-removal processes exist, i.e., scarfing, gouging, washing, etc., this discussion will be confined to oxygen cutting, principally because of its more elemental nature.

The principal related factors that govern the thermochemical removal of metal are:

1. The various heat-transfer mechanisms.
2. The gas dynamics of the oxygen stream.
3. The chemistry and kinetics of the reaction.

R. L. Stoecker and W. B. Moen are associated with the Research Laboratories, Air Reduction Co., Inc., Murray Hill, N. J.

Presented at the 1956 AWS National Fall Meeting in Cleveland, Ohio, October 8-12.

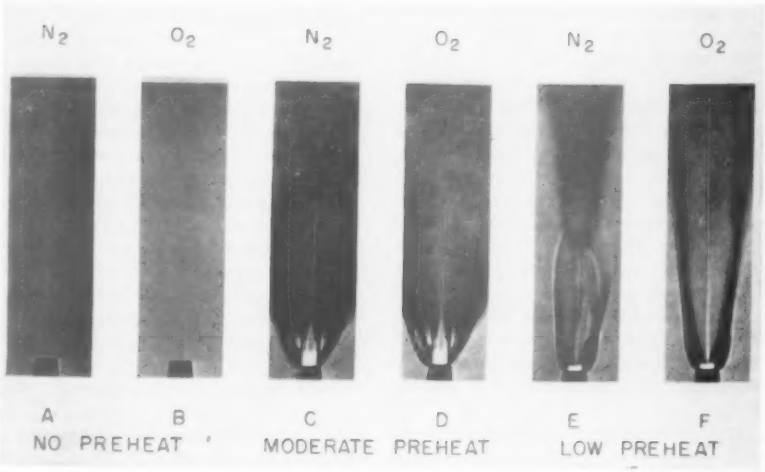


Fig. 1 Effect of preheat on cutting stream

It will be shown that the kinetics of the reaction will set the upper limit on the speed of metal removal. The first two items, however, have a strong contributing effect on the approach to this ultimate reaction rate. In addition, a discussion on additives to the basic iron-oxygen system is presented.

Heat-Transfer Mechanisms

The three primary heat-transfer mechanisms that occur once a cut has been initiated are the energy transfer from the preheat flames to the work, the energy transfer from the preheat flames to the oxygen stream and the energy interchange in the region of the cutting reaction. Each of these are discussed in this section.

It is generally accepted that forced convection is the mode of energy transfer between the preheat flames and the workpiece. A measure of this factor for a combustion system is the combustion intensity. It has been shown that computed values of this term agree well with experimental results for a comparison of various fuel-oxygen ratios as well as for different fuels.[1] It is firmly believed that the only functions of the preheat with respect to the work are to assist in overcoming heat losses from the workpiece to prevent quenching the reaction and to thermally shock scale so that there will be no mechanical barrier to the oxygen stream that will prevent it from entering the kerf.

To determine the effect of the preheat conditions on the oxygen stream, schlieren studies were undertaken. It was shown that the kind of fuel gas, fuel gas-oxygen ratio, and flow rate all have an appreciable effect on the length of coherent oxygen stream issuing from a cutting orifice. For example, the effect of flow rate may be illustrated by referring to Fig. 1. A 0.0595-in. throat-diameter divergent-type cutting tip with an oxygen pressure of 85 psig at the torch entry was used for the study. With no preheat, both the sonic and subsonic portions of the oxygen and nitrogen streams are the same length. With either a low or moderate preheat, the oxygen stream is much longer than the nitrogen stream. It has been reasoned that the cutting-oxygen stream contributes an oxygen supply from its boundary layer to complete the secondary combustion of the preheat flames,

thereby releasing the secondary heat of combustion. This released energy, in turn, partially compensates for the kinetic energy loss of the stream and, consequently, decreases the decay rate. The optimum rate of preheat flow, of course, would contribute the optimum quantity of primary products to obtain a maximum-length oxygen stream but not consume an excessive amount of oxygen (Fig. 1*f*). Figure 2 is a qualitative example of the effect of oxyacetylene preheat on both nitrogen and oxygen streams. Similar effects were noted when heated argon, oxyhydrogen and oxypropane were substituted for oxyacetylene.

Following these optical examinations, a series of cuts was made on 3-in. thick low-carbon steel with a constant cutting-oxygen pressure of 85 psig and with varying degrees of preheat including the value to give the maximum-length coherent cutting stream. Unfortunately, for a desired drag of 10%, no significant change in cutting speed was noted. However, as expected, cut quality was improved at low values of preheat. Apparently the total coherent length of the oxygen stream has little effect on cutting speed.

A heat balance can be written for the energy interchange in the region of the reaction. The energy input is equal to the sum of the heat of combustion of the iron, the energy in the oxygen stream, and the preheat energy. The last two terms are small in comparison with the first and, therefore, are secondary. The heat losses are equal to the energy carried away by the slag and the oxygen stream plus conduction through the workpiece. It is this last term which probably is controlling. Therefore, as long as the rate of heat input represented by the iron-oxygen cutting reaction exceeds the heat loss due to conduction, the reaction cannot thermally quench itself. This balance points to one reason why materials such as copper and aluminum having high thermal conductivities cannot be oxygen cut. The relations computed by Grassman[2] can be applied to prove this point.

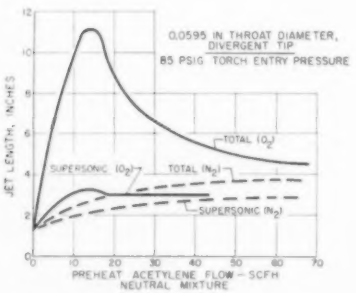


Fig. 2 Effect of preheat flow rate on jet continuity

Gas Dynamics of the Oxygen Stream

The nature of the cutting-oxygen stream affects the cutting reaction in a number of ways. For example, oxygen must be supplied by the stream to sustain the oxidation reaction; it must possess sufficient kinetic energy to assist in the removal of reaction products; and it must maintain a reasonably constant shape and velocity for the full length of the kerf so that it may properly perform the first two functions. Many of the past advances in nozzle design had as the desired end the improvement of these functions. In reality, however, the aim was to more efficiently conserve mass, momentum, and energy in a usable form.

Appreciable effort has gone into the design and development of oxygen cutting tips to efficiently translate the static head of oxygen into kinetic energy with the thought in mind that higher-velocity oxygen streams would permit cutting speed increases without loss of quality. A significant advance was made when the divergent tip was introduced approximately twenty years ago. Improved quality with speed increases averaging 30% over straight-bore nozzles were achieved. It is believed that these improvements are realized because the stream more adequately fulfills the functions mentioned previously. The reason for this, of course, is that the velocity of the jet from a divergent tip is supersonic, whereas the maximum velocity that can be reached from a straight bore tip is sonic.

It appears at this time that little increase in velocity can be attained over that obtainable from a divergent tip unless higher torch entry pressures are used. However, the increase in velocity does not increase at a very high rate when the oxygen pressure passes 200 psig.

There may be one method of improving the oxygen-stream characteristics and that is to overcome the loss of energy caused by interaction of the shock waves in the issuing stream from a divergent tip. Large nozzles, generally one inch and greater in diameter, have been constructed to cancel out the shocks within the confines of the nozzle so that the issuing stream is shockfree but remains supersonic. The characteristics of such a stream compared with conventional streams are shown schematically in Fig. 3. Of course, difficulties can be expected in contouring such nozzles in the small sizes encountered in oxygen cutting tips. Furthermore, the boundary layer corrections are difficult to estimate.

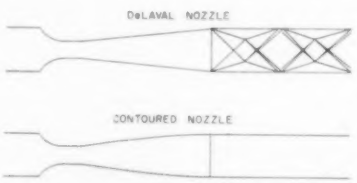


Fig. 3 Comparison of oxygen cutting stream shapes

The previous section on heat transfer included an observation that the coherent length of the oxygen stream as affected by preheat had little, if any, effect on cutting speed. In view of the work already done and the relatively minor speed increases that can be expected by further conditioning the oxygen stream, it is believed that further work at this time is not warranted. Since gross improvements in speed are desired, it is the chemistry and kinetics of the iron-oxygen system which must be explored.

Chemistry and Kinetics of the Reaction

Since it has been shown that heat-transfer mechanisms and gas dynamics are only contributory, the chemistry and kinetics of the reaction must be controlling. In general, oxidation cutting may be defined as rapid oxidation and melting of a narrow kerf in a solid material utilizing a gaseous oxidant. For the continuous propagation of a cut, the chemical reaction between the oxidant and material should be strongly exothermic. As a consequence, the temperature attained should be sufficiently high so as to melt or otherwise enable the reaction products to be removed by the kinetic energy of the

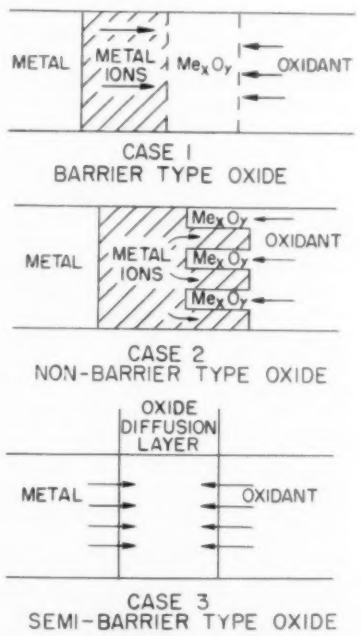


Fig. 4 Schematic representation of oxidation mechanism

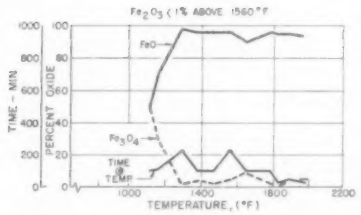


Fig. 5 Percent iron oxide formation vs. temperature[4]

oxygen jet. The temperature range obtained depends on the chemistry of the particular metal-oxygen system being studied. There follows in this section a definition of the reaction and a discussion of the factors which govern it.

Definition of the Reaction

During the oxidation of a metal, the characteristics of the oxide layer can greatly influence the oxidation mechanism. The various types of oxides that can be formed are illustrated schematically in Fig. 4 and discussed below.

CASE I: *Barrier-Type Oxide.* Propagation of the oxidation reaction is dependent on the diffusion of either the oxidant ions (anions) in, or of the metal ions (cations) out through the layer. It is obvious that the character of this oxide layer will influence the rate of oxidation. An excellent example of the "barrier" type oxide formation is the oxidation of aluminum in ambient air. The surface oxide, Al_2O_3, prevents further oxidation in depth by immediately forming an impenetrable oxide layer.

CASE II: *Nonbarrier-Type Oxide.* The "nonbarrier" type oxide is nonadherent such that the oxide only very slightly inhibits the reaction. An example of this effect occurs in the oxidation of sodium or potassium in air which proceeds violently and is not quenched by the products formed.

CASE III: *Semibarrier-Type Oxide.* The semibarrier type layer is similar to Case I except that the diffusion layer formed does not completely inhibit the oxidation. The oxide layer contains defects in the lattice structure that will permit rapid movement of the iron and oxygen ions through the layer. The rate of the over-all reaction then could be a direct function of this movement under certain conditions.

To ascertain the mechanism that occurs when oxygen cutting iron, the characteristics of the oxide formed must be known. The three most common oxides that can be formed are FeO,* Fe_2O_3 and Fe_3O_4. Davies[4] reported that when iron is oxidized in an atmosphere of oxygen at a temperature above approximately 1292° F, 90 to 95% of the oxide formed is ferrous oxide (FeO) (see Fig. 5). The chemical equation for this reaction is:

$$0.947\ Fe(l) + {}^1/_2\ O_2(g) \rightarrow Fe_{0.947}O(l) + 1670\ \text{Btu/lb}$$

Iron is taken as liquid because the temperature of the reaction zone is considerably above the melting temperature of iron.

It should be noted that this reaction indicates the formation of only FeO, whereas previous investigators[5-7] reported the formation of Fe_2O_3 in addition to FeO as shown in Fig. 6. This difference is attributed to the method used to study the oxides. The earlier investigators relied on chemical analysis of the cooled cutting slag to arrive at the reaction products, a method which may be subject to considerable variation caused by:

1. The disproportionation of ferrous oxide to form magnetite in accordance with the reaction:

$$4Fe_{0.947}O(c) \rightarrow Fe_3O_4(c) + 0.788\ Fe(c)^8$$

2. Variation in the method of collecting the slag which will alter the completeness of oxidation of the slag.

3. The use of different plate thicknesses and cutting conditions which can change the ratio of oxide to iron in the slag.[5]

Davies, on the other hand, actually studied the growth of the oxide on pure iron microscopically, utilizing a special furnace with an oxygen atmosphere. The latter's investigation is considerably more reliable and confirms the formation of FeO at temperatures existing during cutting. A temperature of 3250° F has been determined optically at this laboratory confirming the existence of a sufficiently high temperature to produce FeO.

The oxidation of iron to form FeO is of the semibarrier type,[8] thereby permitting its continuous growth. Examination of the simplified Fe-O equilibrium diagram, Fig. 7, reveals that the melting temperature of FeO varies considerably. Although data with regard to the equilibrium of oxygen in iron for higher temperatures than indicated are not known, it is generally accepted[3,8,9] that the equilibrium composition of FeO contains more than the stoichiometric amount of oxygen ($Fe_{0.947}O$). With this in mind, it will be noted that there is a tendency to approach the eutectic temperature of 2500° F, which is considerably lower than the melting temperature of iron, 2800° F. It is obvious that, if the oxide formed has a melting temperature less than the metal itself, the kinetic energy of the oxygen jet and gravitational forces will remove the oxide as it is formed.

Factors Governing the Reaction

From the specific reaction equation, it is known that the specific rate constant of a chemical reaction is equal to the number of collisions between reactant molecules multiplied by a factor expressing the efficiency of the collisions. This relationship is known as the Arrhenius equation and is given by:

$$k = f(A)e^{-E/RT}$$

where:

k = specific reaction rate.
$f(A)$ = collision frequency.
e = 2.718 (Napierian logarithm base).
E = energy of activation.
R = universal gas constant.
T = absolute temperature.

The term (A) is expressed as a function since it is influenced by other variables such as phase, pressure and type of oxide formed. This relationship shows the importance of product formation and disposition. As previously indicated for the barrier-type oxide layer which is practically impervious, $f(A)$ can approach zero and the reaction can be quenched. Conversely, in the iron-oxygen system which forms a fluid slag and is illustrated by Case III, $f(A)$ can assume a definite upper limit which determines the rate of the reaction.

The temperature dependence is logarithmic and accounts for the increase in cutting speed obtainable when hot cutting as shown in Fig. 8.[6] One might question the validity of this observation, as the curve shown in Fig. 8 does not

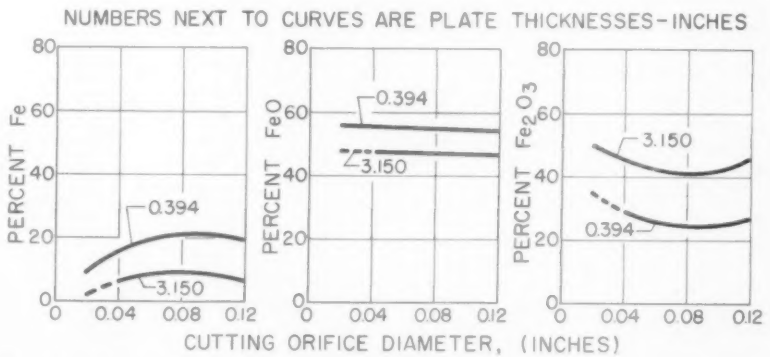


Fig. 6 Chemical analysis of cutting slag[5]

* FeO has several equilibrium compositions, the most generally accepted being $Fe_{0.947}O$.[3]

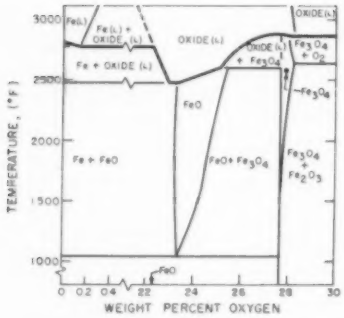


Fig. 7 Simplified Fe-O equilibrium diagram[10]

illustrate the logarithmic dependence on temperature. The variance is caused by the formation of a heavy scale (Fe_2O_3 and Fe_3O_4) on the surface of the metal due to heating the metal in air. This scale must be melted by the combustion of iron below the scale, and as a result, the over-all speed of the reaction is reduced. This factor also accounts for gouging when hot cutting, where the rate of reaction at the lower portion of the cut is greater than at the very top.

The importance of oxide removal and oxygen pressure in cutting can be illustrated by the use of the mass action law which states that the ratio of the activity of the reaction products to the product of the activities of the reactants is a constant. A simplified expression for the equilibrium constant for the formation of FeO is given by the relation:

$$K = \frac{a_{FeO}}{a_{Fe} \cdot a_{O_2}^{1/2}}$$

where the a's are the respective activities of the reactants and products. The activity of iron in its standard state is approximately one, and the activity of oxygen is approximately equal to its partial pressure. The expression then becomes:

$$K = \frac{a_{FeO}}{P_{O_2}^{1/2}}$$

It is apparent from this relationship that the rate of reaction is favored by the removal of FeO and is directly proportional to the square root of the oxygen partial pressure.

Summary of the Reaction

From the foregoing discussion, a simplified model of the reaction can be described. The preheating flames heat the iron to a temperature in excess of 1292° F, whereupon the oxygen gas can combine directly with the iron to form a fluid oxide. Since the oxide (FeO) has a melting temperature less than that of the metal it flows under the influence of the gas jet and gravitational forces thereby exposing fresh iron. The heat evolved from the reaction is transferred to the underlying surfaces at the cut interface very efficiently because it is liquid. The reaction rate is inversely proportional to the partial pressure of the oxygen and proportional to the rate of removal of the oxide. Thus, it would seem that the rate at which the oxide is removed is rate determining and the fact that the iron ions diffuse to the oxygen assists in making the over-all reaction rate high.

Influence of Additives on the Reaction

In the foregoing discussion the idealized case of pure oxygen reacting with pure iron was reviewed. This condition, however, is not the case in actual cutting practice. It is for this reason that the following discussion which covers the influence of alloying elements in the iron and the effect of impurities in the oxygen has been included.

The Influence of Alloying Elements in the Iron

The foregoing analyses are helpful in rationalizing the effects of alloying elements on the cutting reaction. The first major factor to be considered is the difference between the melting temperature of the oxide and that of the alloy.

It will be recalled that FeO possesses a melting temperature which is less than that of pure iron. It can be seen from Table 1 that very few materials possess this property.

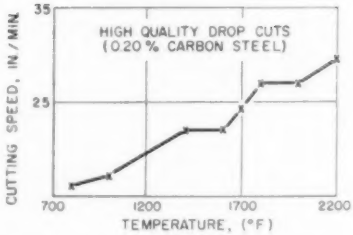


Fig. 8 Cutting speed as a function of temperature[6]

It is also shown that small additions of alloying elements to iron lower the melting temperature of the alloy. This also occurs to the oxide mixture but to a lesser extent. As an example of this, consider the following combinations: iron-aluminum, iron-manganese and iron carbon.

1. *Iron-Aluminum.* Alloying aluminum with iron in an amount of 10 to 15% causes difficult cutting.[11] A comparison of the liquidus lines of Fe-Al and FeO-Al_2O_3, (Fig. 9) reveals that the limiting percentage of alloying element corresponds to the range where the melting temperature of the oxide approaches that of the metal.

2. *Iron - Manganese.* Comparison of the liquidus lines for Fe-Mn and FeO-MnO (Fig. 10) shows a similar

Table 1—Element and Oxide Properties[9-14]

Element	*Oxide*	*Element melting temperature, ° F*	*Oxide melting temperature, ° F*	*Thermal conductivity of element, Btu/hr-ft²-° F/ft**	*Heat of formation of oxide, Btu/lb†*
Al	Al_2O_3	1220	3659	128	7060
B	B_2O_3	4172	1071	...	7890
Ca	CaO	1490	4658	73	4850
C	CO	6690	...	14	1700
	CO_2	...	...	...	3840
Cr	CrO_2	2939	572	39	3060
	CrO_3	...	388	...	2520
	Cr_2O_3	...	3452	...	3220
Co	CoO	2723	3272‡	39	1370
	Co_3O_4	...	...	...	1550
Cu	CuO	1981	2637	227	850
	Cu_2O	...	2255	...	520
Fe	$Fe_{0.947}O$	2795	2516	44	1670
	Fe_2O_3	...	2854‡	...	2220
	Fe_3O_4	...	2800‡	...	2070
Mg	MgO	1204	5072	92	6370
Mn	MnO	2273	3002	...	2340
	MnO_2	...	995	...	2580
	Mn_2O_3	...	3101	...	2610
	Mn_3O_4	...	1976	...	1810
Mo	MoO_2	4757	...	85	1870
	MoO_3	...	1463	...	2250
Ni	NiO	2651	3794	53	1380
Si	SiO_2	2606	3110	48	6290
Na	Na_2O	...	1683	77	2880
	Na_2O_2	...	860	...	2830
Ti	TiO	3326	1816	37	3480
	TiO_2	...	2984	...	5090
	Ti_2O_3	...	3866	...	4550
	Ti_3O_5	...	...	...	4720
W	WO_2	6180	2678	92	1550
Zr	ZrO_2	3182	4892	...	3820

* At or near room temperature. † From the elements at 76° F. ‡ Decomposes.

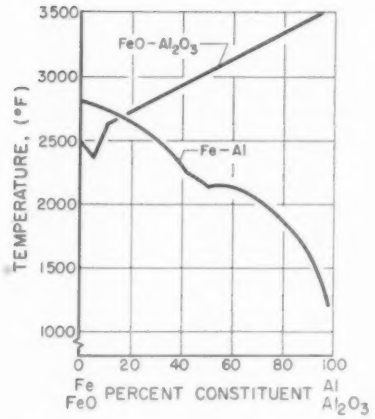


Fig. 9 Liquidus lines for the systems Fe–Al and FeO–Al_2O_3[11, 15]

condition for approximately 14% manganese at which amount this alloy is difficult to cut.[11]

3. *Iron-Carbon.* Carbon content above 2% in iron reduces its susceptibility to cutting.[11] Again, use of the liquidus line will prove helpful. Referring to Fig. 11, it can be seen that the melting temperature of Fe-C at 2% carbon corresponds to the melting temperature of FeO (Fig. 7).

The presence of oxides which are liquid or solid at the reaction temperature will inhibit the exposure of fresh metal to the oxygen stream. This is not the only factor that need be considered in an analysis of this type, as other properties of the metals or oxides may override the incompatibility of the melting temperatures.

Other factors of concern are (not given in the order of importance since the relative importance of each may vary for different systems):

(*a*) Viscosity of the oxides formed. The kinetic energy necessary to move a fluid varies directly with the viscosity of the fluid. Hence, oxides with a high viscosity offer flow resistance to the oxygen jet and thereby inhibit the exposure of fresh iron to the oxygen stream.

(*b*) Crystallographic characteristics of the oxide layer.[4, 9, 16, 17] The development of X-ray diffraction techniques, radioactive tracers and the electron microscope has provided methods for studying closely the crystallographic structure of oxides. Investigations utilizing these tools have shown that the movement of ions within or through the lattice structure varies widely depending on the kind and type of oxide structure.

(*c*) Heat of formation of the oxide formed at the cutting temperature. The evolution of large amounts of heat from the formation of the oxide has two major functions: first, it provides the heat necessary to keep the reaction going and, second, it increases the fluidity of the oxides formed if they are liquid.

(*d*) Heat of fusion of the material. Since the ratio of the heat of fusion of the metal to the heat of combustion of the metal with the exception of copper and nickel never exceeds 0.05, this property is considered unimportant. Even with nickel where the ratio is 0.10, its effect as an alloying element in stainless steel is insignificant. In the case of copper the thermal conductivity probably is more important.

(*e*) Vapor pressure of the products formed. It is obvious that the vapor pressure of carbon monoxide will reduce the partial pressure of oxygen when cutting carbon steels.

(*f*) Diffusion potential. The rate of diffusion varies for each of the metals. Smithells[12] gives excellent data on diffusion rates which may prove helpful when considering selective oxidation phenomena. An example of selective oxidation occurs in stainless steels wherein chromium oxidizes in preference to nickel because of the higher diffusion rate of chromium in iron.

(*g*) Heat capacity of the elements. With few exceptions, the mean heat capacities between ambient and ignition temperatures for various materials are relatively close. Consequently, this property need not be considered in comparing the ability of various material to be cut.

Effect of Oxygen Purity

The influence of oxygen purity on the rate of oxidation (cutting speed) is shown in Fig. 12. This curve shows that for slight increases in oxygen purity in the high purity range, one would expect great increases in speed. This relationship also has been shown by Gunnert.[18] An interesting side light to experiments of this type is the technique used. In both the cases cited, a limiting degree of drag was taken as the criterion for the tests. This assumes that the amount of drag (expressed as a percent curvature of the drag lines) is directly related to the

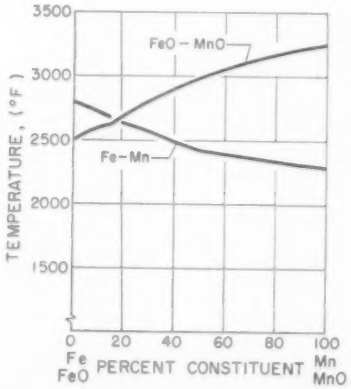


Fig. 10 Liquidus lines for the systems Fe–Mn and FeO–MnO[11, 15]

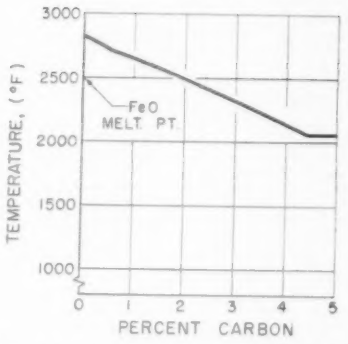


Fig. 11 Liquidus line for the Fe-C system[11]

reaction rate, which may or may not be true. In addition, drag is a difficult parameter to measure. The net effect of these factors may tend to exaggerate the results reported in Fig. 12, indicating to the unwary that the cutting speed could approach infinity as the purity approaches 100%. It is believed that the true curve will follow the path indicated rather than be asymptotic.

There are two effects of impurities on the cutting oxygen, each of which is discussed below.

1. The value of $f(A)$ in the Arrhenius relationship is reduced (fewer collisions of reactant molecules). The relationship which expresses the statistical collision between two gases is given by:[19]

$$Z = {}^1/_4\, n_a n_b (\sigma_a + \sigma_b)^2 \times \left[8\pi RT\,\frac{(M_a + M_b)}{M_a M_b}\right]$$

in which n_a and n_b are the numbers of molecules/unit volume; M_a and M_b are the molecular weights of the gases and σ_a and σ_b are the collision diameters of a and b. Values for σ and M for various gases are given in Table 2.[19] In Table 2, the constants n_a, n_b, π, R and T have been factored such that:

$$Z \sim \psi = (\sigma_{a_2} + \sigma_b)^2 \left[\frac{M_{O_2} + M_b}{M_{O_2} M_b}\right]^{1/2}$$

It is apparent that Z is proportional to the number of molecules present and that collisions that occur between oxygen and the diluent will reduce the number of collisions between the oxygen and iron. The effect is to reduce the value of $f(A)$ which in turn reduces the reaction rate. It would be expected then that small additions of nitrogen, for instance, would have less influence than an equal amount of argon as indicated by the values of ψ.

2. The partial pressure of the oxygen is reduced. The dependence of the rate of reaction on partial pressure has been shown before to vary with the square root of the oxygen partial pressure. This explains in part the parabolic dependence of speed on purity as shown in Fig. 12.

Table 2—Relative Effect of Gaseous Additives to the Oxygen Stream

Gas	$\sigma \times 10^8$, *cm*	*Mol. wt.*	$\psi \times 10^{16}$
O_2	3.61	32.0	...
A	3.64	39.94	12.5
Air	3.72	28.96	13.77
N_2	3.75	28.02	14.0
CO_2	4.59	44.01	15.6
He	2.18	4.002	16.8
H_2O	4.60	18.02	19.80
H_2	2.74	2.016	29.40

The actual dilution caused by the atmosphere of air or combustion products surrounding the oxygen jet is difficult to determine. However, if only the portion of the jet between the tip exit and the workpiece is considered, it can be shown that little dilution may occur. Figure 13 shows a jet surrounded by atmospheric air. It is known that the boundary layer of the flowing jet across which there is considerable energy loss is very small. The energy within this layer is composed of translational and rotational molecular energy in a tightly compacted zone. It is conceivable that there is little opportunity for the surrounding atmosphere to penetrate this layer and be carried with it.

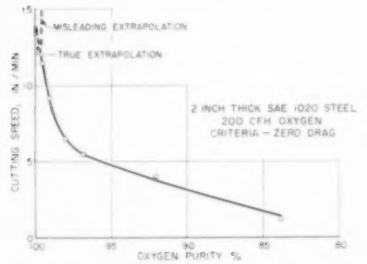


Fig. 12 Cutting speed for quality cuts vs. oxygen purity[6]

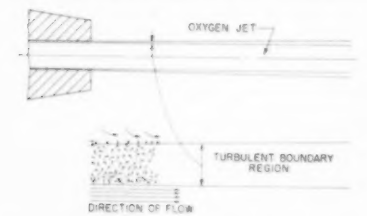


Fig. 13 Enlarged sketches of the boundary layer

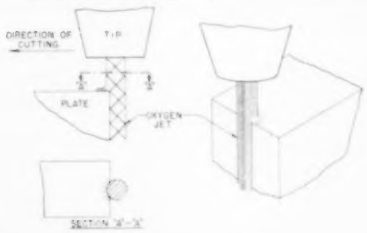


Fig. 14 Enlarged sketches illustrating interference between the oxygen jet and the reacting surface

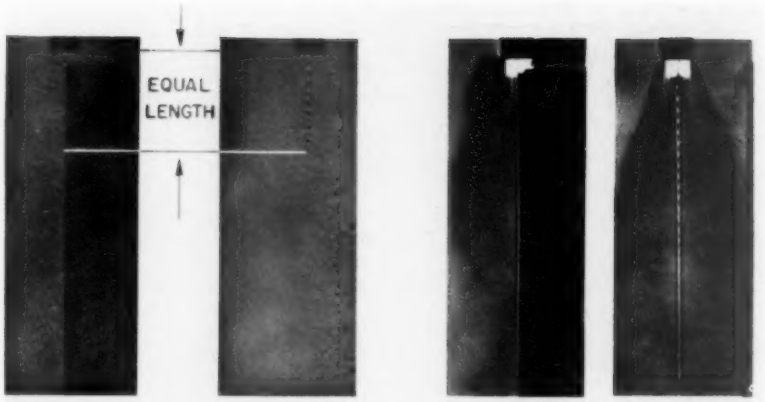


Fig. 15 Influence of surface interference on the oxygen jet

In addition to this, visual observation of actual cutting will reveal that the effective portion of the oxygen jet at the metal oxygen interface is not composed of the boundary layer surrounding the jet prior to entering the kerf. This occurrence is illustrated by the sketches in Fig. 14.

The schlieren photographs, Fig. 15, portray the effect of a surface on the oxygen jet. In the case of the unheated jet, it will be noted that the visible length of the jet in both cases is the same. The heated jet does not show this similarity; however, it can be seen that the continuity of the heated jet along the surface is improved. It is possible, therefore, that the position of the jet relative to the metal interface is established automatically by the equilibrium conditions of the reaction. This equilibrium can be upset by either too fast or too slow a cutting speed. In any case, the oxygen jet must maintain sufficient interference with the metal to permit exposure of the hot reaction zone to high-purity oxygen.

It may be concluded, therefore, that contamination of the oxygen jet by the combustion products before the jet enters the kerf need not be considered as having a diluting effect on the cutting action at the metal-oxygen interface.

Summary

It has been shown that the chemistry of the iron-oxygen system is the significant factor that permits iron to be oxygen cut. The aerodynamics of the oxygen stream and the various heat transfer mechanisms, while important, only assist in propagating the reaction. It is believed that the kinetics of the iron-oxygen reaction sets the upper limit on the cutting speed and that additives to the reaction will only alter this maximum limit. One may conclude that increases in cutting speed may be achieved by methods that will remove the oxide formed at a faster rate. Faster oxide removal will permit more metal and oxidant to react in a given time which, in turn, will provide a higher temperature gradient, and a higher diffusion rate through the barrier.

Acknowledgments

The authors wish to express their appreciation to the Air Reduction Co., Inc., for its permission to present this paper. Dr. R. O. Seitz and W. E. Stubbs of this laboratory have been most helpful in translating foreign publications and photography, respectively.

Bibliography

1. Moen, W. B., and Campbell, J., "Evaluation of Fuels and Oxidants for Welding and Associated Processes," The Welding Jnl., **34**, (9), 870–876 (1955).
2. Grassman, P., "Calculation of Temperature Distribution in Oxygen Cutting," *Z. angew. Physik*, **4**, 455–458 (1952).
3. Humphery, G. L., King, E. G., and Kelly, K. K., "Some Thermodynamic Values for Ferrous Oxide," Bureau of Mines, RI 4870 (1953).
4. Davies, M. H., Simnad, M. T., and Birchenall, C. E., "On the Mechanism and Kinetics of the Scaling of Iron," *Jnl. Metals*, **3**, 889 (1951).
5. Malz, H., *Die Grenzen der Schneidgeschwindigkeit beim Brennschneiden* (*The Limit of Cutting Speed for Gas Cutting*), Konrad Triltsch, Wurzburg (1933).
6. Slottman, G. V., and Roper, E. H., *Oxygen Cutting*, McGraw-Hill, New York (1951).
7. Spraragen, W., and Claussen, G. E., "Oxygen Cutting of Steel," The Welding Jnl., **18** (7), 217-s to 248-s Research Suppl., (1939).
8. Hauffe, K., and Pfeiffer, H., "The Kinetics of Wustite Formation in the Oxidation of Iron," *Z. Metallkinde*, **44**, 27–36 (1953).
9. Kubaschewski, O., and Hopkins, B. E., *Oxidation of Metals and Alloys*, Academic Press, New York (1953).
10. Darken, L. S., and Gerry, R. W., *Physical Chemistry of Metals*, McGraw-Hill, New York (1953).
11. *Metals Handbook*, American Society for Metals, Cleveland, Ohio (1948).
12. Smithells, C. J., *Metals Reference Book*, 2d ed., 2v. Interscience Publishers, New York, (1955).
13. *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, Ohio (1954).
14. Lange, N. A., *Handbook of Chemistry*, Handbook Publishers, Inc., Sandusky, Ohio (1952).
15. Hall, F. P., and Insley, H., "Phase Diagrams for Ceramists," *Jnl. Am. Ceram. Soc.*, **30**, Part 2 (Nov. 1, 1947) Ibid, Part 2 (Dec. 1, 1949).
16. "Pittsburgh International Conference on Surface Reactions," Corrosion Publishing Co., Pittsburgh, Pa. (1948).
17. Hickman, J. W., and Gulbransen, E. A., "An Electron Diffraction Study of Oxide Films on Iron, Cobalt, Chromium, Copper, Nickel, Molybdenum, Tungsten and Alloys of Molybdenum, Tungsten and Nickel at High Temperatures," *Trans. Am. Inst. Mining Met. Engrs.*, **171**, 306–388 (1947).
18. Gunnert, R., "The Effect of Oxygen Purity on Speed and Gas Consumption in Oxygen Cutting," *Schweissen u. Schneiden*, **7** (2), 58–59 (1955).
19. Kennard, E. H., *Kinetic Theory of Gases*, McGraw-Hill, New York (1938).

PROPERTIES AND WELDABILITY OF HIGH-STRENGTH PRESSURE-VESSEL STEELS IN HEAVY SECTIONS

Object of investigation sponsored by two committees of the Welding Research Council is to show the effects of plate thickness and of position in the plate on the mechanical properties and weldability of the steels in question

BY J. H. GROSS AND R. D. STOUT

FOREWORD. The investigations reported here were conducted under the sponsorship of the Pressure Vessel Research Committee and the Weldability Committee of the Welding Research Council. The authors are grateful for this support and for the valuable assistance rendered by members of these committees.

Introduction

In a previous investigation[1] the mechanical properties and weldability of six high-strength steels were studied with the object of determining their suitability for application in pressure vessels designed to higher than conventional stress levels. To the extent that laboratory tests can be used for this purpose, the results were encouraging. The question next arose as to the changes that might be necessary in these conclusions if the section thickness were increased to 4 in. Applications such as nuclear reactor vessels and vessels for the chemical industry involve pressures that require excessive thicknesses of carbon steel at normal design stresses. Accordingly, the study was extended to 4-in. sections of a carbon steel and three high-strength steels of 50,000, 70,000 and 90,000 psi minimum yield strengths. The object of this investigation was to study the effects of plate thickness and of position in the plate on the mechanical properties and weldability of high-strength pressure-vessel steels.

Steels and Testing Schedule

The steels chosen for testing were the following: A201 Grade A, A302 Grade B, Navy G (Navy HY65) and T-1 steel. Their chemical compositions and mill heat treatments are given in Table 1. Typical microstructures of the heavy-section steels are shown in Fig. 1. The steels were received as 1-ft wide, 4-ft long and 4-in. thick sections of plate with the 4-ft dimension parallel to the rolling direction. The sections were cut from essentially the full width of the rolled plate and were identified to permit sampling from the center and edge of the plate width.

The testing schedule was set up to permit not only a comparison of properties between the 1-in. plates and the 4-in. plates but also between locations with respect to the width and the thickness dimensions of the 4-in. plate. A condensed schedule of tests is given in Table 2.

Test Results and Discussion

A complete listing of the test results for the steels is given in Tables 3 to 6. The properties for the 1-in. plates are included in the tables for direct comparison. While the tables contain the data necessary for showing the various effects, the data are in a highly indigestible form for analysis. Therefore, an attempt was made to assemble the data into bar graphs to facilitate comparisons. In order to assign the maximum weight to the values in the graphs, the data were lumped into two groups to be compared at any one time. Thus all longitudinal tension tests were averaged for comparison with the average of all transverse tests. Likewise, all mid-thickness values were lumped to compare to the quarter-thickness values and so on.

Tensile Properties

Full-section tension tests were performed on the four heavy-section steels. No standard ASTM specimen is designated for plate of this thickness. The specimen chosen was 6 in. wide by 48 in. long by full plate thickness. The test section was 4 in. by 4 in. in cross section with a 16-in. gage length. The dimensions have the same 4:1, length-to-diameter ratio, specified in the standard 0.505-in. specimen. Photographs of the reassembled fractured specimens and the fracture surfaces are shown in Fig. 2.

Figure 3 compares the standard tensile properties of the full-section 4-in. specimens to the average values of all longitudinal 0.505's and the full-section 1-in. specimens. The values of strength obtained on the full-section 4-in. specimens check well with the 0.505-in. tests. Ductility values were consistently lower in the full-section tests than in the 0.505-in. tests, particularly for reduction of area. This effect undoubtedly arises from the difference of geometry between the two types of specimens. Further comparisons between 1-in. and 4-in. plates will be made on the basis of 0.505-in. tests, since with a few minor exceptions, the full-section tests showed the same trends as the small tests.

In Fig. 4, the yield strengths of 0.505-in. specimens tested at room temperature are compared. A201 showed no significant effects of plate thickness or position. A302 had a higher yield in 4-in. thickness than in the 1-in. plate. There was also a somewhat higher yield at the quarter-thickness than at the mid-thickness. The 4-in. Navy G steel was considerably higher in yield strength than the 1-inch. T-1 steel had a considerably lower yield strength in the 4-in. plate.

J. H. Gross and R. D. Stout are associated with the Metallurgy Department, Lehigh University, Bethlehem, Pa.

Presented at the 1956 AWS National Fall Meeting in Cleveland, Ohio, October 8–12.

Table 1—Chemical Composition and Mill Processing and Specifications of Steels

Steel	Chemical analysis, % C	Mn	P	S	Si	Ni	Cr	Mo	V	Ti	Cu	B	Mill processing
A-201*													
1-in. plate:													
Heat analysis	0.11	0.44	0.014	0.030	0.16	..	..	..	..	...	..	...	Hot rolled.
Plate analysis	0.12	0.42	0.016	0.028	0.16	..	..	..	..	...	..	...	
4-in. plate:													
Heat analysis	0.15	0.47	0.013	0.027	0.19	..	..	..	..	...	..	...	272 ton—14 ingot—basic OH heat—Si and Ti deoxidized, No. 4 ingot (37 x 58, 38,630 lb) bottom cut finished at 1875° F to 144 x 72 x 4-in. plate, test plate 48 x 72 in., normalized at 1650° F.
Plate-surface	0.16	0.52	0.015	0.022	0.21	..	..	..	..	...	..	...	
Quarter-thickness	0.16	0.49	0.015	0.023	0.21	..	..	..	..	...	..	...	
Mid-thickness	0.14	0.50	0.012	0.017	0.20	..	..	..	..	...	..	...	
A-302†													
1-in. plate:													
Heat analysis	0.19	1.32	0.022	0.029	0.25	..	..	0.43	..	...	..	...	Normalized.
Plate analysis	0.20	1.32	0.022	0.030	0.25	..	..	0.42	..	...	..	...	
4-in. plate:													
Heat analysis	0.20	1.40	0.017	0.027	0.26	..	..	0.44	..	...	..	...	120 ton—5 ingot—basic OH heat—Si and Al deoxidized, No. 3 ingot (23 x 70, 25,000 lb) finished at 1900° F to 146 x 73 x 4-in. plate, test plate 48 x 73 in. normalized at 1675° F and tempered at 1200° F.
Plate surface	0.17	1.43	0.013	0.025	0.23	..	..	0.51	..	...	..	...	
Quarter-thickness	0.21	1.40	0.018	0.025	0.25	..	..	0.49	..	...	..	...	
Mid-thickness	0.19	1.42	0.016	0.024	0.23	..	..	0.50	..	...	..	...	
Navy G‡													
1-in. plate:													
Heat analysis	0.12	0.42	0.006	0.027	0.20	2.23	..	0.42	0.11	...	0.72	...	Normalized and tempered.
Plate analysis	0.12	0.48	0.013	0.032	0.21	2.16	..	0.39	0.11	...	0.70	...	
4-in. plate:													
Heat analysis	0.11	0.45	0.012	0.023	0.18	2.48	..	0.54	0.11	...	0.65	..	25 ton—1 ingot (39 x 57, 45,820 lb)—basic OH heat-fine grain killed, longitudinally slabbed (19¾ x 50 x 119, 32,020 lb—finished at 2050° F). Transverse rolled (4 x 122 x 218, 32,020 lb). Normalized at 1650° F and tempered at 1150° F.
Plate surface	0.12	0.50	0.016	0.023	0.16	2.55	..	0.55	0.12	...	0.63	...	
Quarter-thickness	0.12	0.51	0.015	0.022	0.16	2.58	..	0.55	0.12	...	0.63	...	
Mid-thickness	0.12	0.51	0.016	0.023	0.16	2.55	..	0.56	0.12	...	0.62	...	
T-1‡													
1-in. plate:													
Heat analysis	0.15	0.92	0.014	0.020	0.26	0.88	0.50	0.46	0.06	...	0.32	0.0031	Quenched and tempered.
Plate analysis	0.16	0.93	0.014	0.023	0.26	0.87	0.50	0.45	0.06	...	0.33	...	
4-in. plate:													
Heat analysis	0.15	0.72	0.016	0.016	0.26	0.86	0.63	0.55	0.05	0.008	0.46	0.003	250 ton—12 ingot—basic OH heat-fine grain killed, No. 4 ingot (32 x 60, 36,380 lb), longitudinally slabbed (20 x 55 x 88, 26,200 lb). Transverse rolled 4 x 80 x 148 13,400 lb and 4 x 80 x 60, 5800 lb). Austenitized 1700° F—quenched and tempered at 1225° F.
Plate surface	0.14	0.84	0.016	0.016	0.30	0.87	0.61	0.53	0.05	0.006	0.41	0.004	
Quarter-thickness	0.15	0.85	0.017	0.016	0.29	0.87	0.63	0.52	0.05	0.006	0.43	0.004	
Mid-thickness	0.14	0.81	0.016	0.016	0.27	0.84	0.61	0.50	0.05	0.006	0.41	0.004	

* ASTM A201–54T (Grade A, firebox, 4-in. thickness). C, 0.27% max, tensile strength, 55,000–65,000 psi. Yield point, 30,000 psi min. Elongation (2 in.), 28.5%, min.

† ASTM A302–54T (Grade B, firebox, 4-in. thickness). C, 0.25% max, Mn, 1.15–1.50%, P, 0.035% max, S, 0.040% max, Si, 0.15–0.30%, Mo, 0.40–0.65%, tensile strength, 80,000–100,000 psi. Yield point, 50,000 psi min. Elongation (2 in.), 19.5%, min.

‡ Not covered by ASTM Standards.

This was due in part to the 25° F higher tempering temperature of the 4-in. plate. The effect of plate position on the yield strength of Navy G and T-1 was negligible.

Figure 5 is a compilation of the room temperature 0.505-in. tensile strengths. A201 and A302 exhibited no significant effects of plate position or thickness. The tensile strength increase of 4 in. over 1 in. in Navy G plate and the decrease for T-1 were consistent with the yield strength observations. Plate position was without effect.

The largest variation in the elongation values of the room temperature 0.505-in. specimens was observed between the two plate thicknesses as shown in Fig. 6. Four-inch A201 plate displayed a substantial increase over the 1-in. plate for a constant tensile strength, while the 4-in. A302 plate showed slightly better ductility despite an increase in tensile strength. The decrease in elongation for Navy G and increase for T-1 were undoubtedly associated with their respective increase and decrease in strength. Slight variations in elongation due to plate position are noticeable in A201 center vs. edge and A302 mid-thickness vs. quarter-thickness. Differences of the same order were noted in the tensile strengths.

The room temperature tests on 0.505-in. specimens shown in Fig. 7 indicate that reduction of area values follow very closely the trends observed for elongation.

Increase in testing temperature to 550° F for transverse 0.505-in. specimens produced, in general, the effects observed in 1-in. plate as depicted in Fig. 8. Yield strength decreased moderately while elongation and reduction of area decreased markedly, as is characteristic in the blue brittle range. A201 steel increased appreciably in tensile strength by strain aging. This phenomenon is less pronounced in aluminum-killed, fine-grained steels such as A302, Navy G and T-1. In this instance the alloy steels underwent a slight decrease in tensile strength at the elevated testing temperature.

A more complete survey of strength variations across the thickness was made by Brinell testing. The uniformity in hardness over the entire thickness, reported in Table 7, confirms the results of the tension tests at the quarter- and mid-thickness points.

Notch-Toughness Properties

The notch toughness of the plates was determined by V-notch Charpy tests. The transition temperatures based on 15 ft-lb are plotted in Fig. 9. The transition temperature of the heavy-section steels was essentially independent of plate position. Substantial differences were observed between the 1- and 4-in. alloy plates. The 4-in. A302 had a lower transition temperature than the 1-in. plate both as-received and as-strain aged. The fine-grain melting practice and the stress-relieving treatment, applied to the 4-in. plate only, may account for some of the improvement in ductility and notch toughness in the face of increased tensile strength. The higher transition temperature and lower ductility in the 4-in. Navy G steel compared to 1 in. was undoubtedly associated with a large increase in tensile strength. On the other hand, T-1 steel in the 4-in. section had both lower strength and higher transition temperatures than did the 1-in. plate despite an increase in ductility.

It should be noted that the transition temperatures of the alloy steels were lower than the A201 carbon steel as-received or prestrained.

Welded Properties

The welded notch toughness of the 4-in. plate was determined on 1-in. thick Kinzel specimens cut from the quarter-thickness location and tested on an 11-in. span. Weld beads were deposited with the standard qualified electrodes previously reported[1] for the 1-in. thick plates. The relative behavior is compared in Fig. 10. In all cases, the 4-in. plates showed a lower welded notch toughness than the 1-in. plates. Stress relieving appreciably improved only the A302 and Navy G steels, with the net result that the four steels showed much less spread in transition temperature after stress-relief treatment.

Full-section Kinzel tests were run on A201 steel only, in the as-received, as-welded and stress-relieved conditions.

Table 2—Schedule of Heavy-Section Tests Performed

A. Tension tests for yield strength, tensile strength, elongation and reduction of area (duplicate specimens)
   1. Room temperature—Full-plate thickness—Center of plate—Longitudinal
   2. Room temperature—0.505 in.
      (*a*) Center of plate—One-quarter thickness—Longitudinal
      Center of plate—One-quarter thickness—Transverse
      Center of plate—Mid-thickness—Longitudinal
      Center of plate—Mid-thickness—Transverse
      (*b*) Edge of plate—One-quarter thickness—Longitudinal
      Edge of plate—One-quarter thickness—Transverse
      Edge of plate—Mid-thickness—Longitudinal
      Edge of plate—Mid-thickness—Transverse
   3. Elevated temperature—550° F—0.505 in.
      (*a*) Center of plate—One-quarter thickness—Transverse
      (*b*) Center of plate—Mid-thickness—Transverse

B. V-notch Charpy tests of base metal for ductility and fracture transition temperature
   1. As-received plate
      (*a*) Center of plate—One-quarter thickness—Longitudinal
      Center of plate—Mid-thickness—Longitudinal
      (*b*) Edge of plate—One-quarter thickness—Longitudinal
      Edge of plate—Mid-thickness—Longitudinal
   2. Tensile prestrained 5% and aged 1 hr at 550° F
      (*a*) Center of plate—One-quarter thickness—Longitudinal
      Center of plate—Mid-thickness—Longitudinal

C. Cantilever beam fatigue tests for allowable strain range for 100,000 cycle fatigue life
   1. Center of plate—One-quarter thickness—Longitudinal
   Center of plate—Mid-thickness—Longitudinal

D. Kinzel tests for transition temperature
   1. One-inch thick specimens
      (*a*) Edge—One- and three-quarter-thickness—Longitudinal—Unwelded
      Edge—One- and three-quarter-thickness—Longitudinal—Welded
      Edge—One- and three-quarter-thickness—Longitudinal—Welded and stress relieved
   2. Full-plate thickness specimens (A201 steel only)
      (*a*) Quarter-width—Longitudinal—Unwelded
      Quarter-width—Longitudinal—Welded
      Quarter-width—Longitudinal—Welded and stress relieved

E. Longitudinal—Bead-weld—Underbead cracking tests
   1. Two-inch thick specimens—Top surface
      Two-inch thick specimens—One-quarter thickness
      Two-inch thick specimens—Mid-thickness
      Two-inch thick specimens—Three-quarter thickness
      Two-inch thick specimens—Bottom surface
   2. Full-plate thickness—Top surface
      Full-plate thickness—Bottom surface

F. Metallographic and Hardness Survey

Table 3—Test Data on A201 Steel

Tensile properties

Location	*0.2% offset yield strength, psi*	*Tensile strength, psi*	*Elongation, %*	*Reduction in area, %*
Full-section tension tests (room temperature)				
4-in. full section	28,200	54,600	34.4	54.9
	28,400	55,100	35.4	54.9
4-in. longitudinal—0.505's	28,500	55,500	37.4	64.7
1-in. full section	29,900	53,000	29.7	61.8
0.505-in. tension tests—room temperature				
One-inch longitudinal	29,700	54,800	33.8	65.8
Four-inch longitudinal				
Center, 1/4 thickness	28,700	55,300	39.0	66.0
	26,900	55,800	38.0	64.5
Center, mid-thickness	28,600	53,400	38.5	68.8
	27,600	54,000	39.0	67.8
Edge, 1/4 thickness	29,300	56,900	34.5	64.1
	29,000	57,400	38.0	60.1
Edge, mid-thickness	29,800	57,000	37.0	64.7
	28,800	57,000	36.0	62.6
One-inch transverse	29,800	53,800	29.7	50.4
Four-inch transverse				
Center, 1/4 thickness	25,800	56,000	36.5	59.2
	26,800	56,500	35.0	60.1
Center, mid-thickness	27,600	53,500	34.5	59.5
	29,100	54,600	37.0	57.0
Edge, 1/4 thickness	27,700	55,300	35.5	59.4
	29,400	57,800	34.0	60.5
Edge, mid-thickness	30,300	59,800	34.0	56.0
	29,600	56,800	33.0	59.6
0.505-in. tension tests—550° F				
One-inch longitudinal	24,600	69,300	24.8	52.6
Four-inch transverse				
Center, 1/4 thickness	22,300	74,100	25.5	47.7
	24,400	72,300	22.5	44.6
Center, mid-thickness	21,300	67,300	28.0	53.8
	20,600	67,600	25.5	48.2

Cantilever beam fatigue tests

Location	*Allowable strain range at 100,000 cycles, %*
Three-quarter inch plate (Tensile strength, 57,800 psi)	0.34
Four-inch plate	
Center, 1/4 thickness	0.45
Center, mid-thickness	0.46

Charpy V-notch tests*

	15 ft-lb transition temperature, ° F	*50% fibrous fracture transition temperature, ° F*
One-inch plate	30	65
Four-inch plate		
Center, 1/4 thickness	30	85
Center, mid-thickness	25	85
Edge, 1/4 thickness	40	100
Edge, mid-thickness	35	95
One-inch plate		
5% prestrain + 1 hr at 550° F	110	135
Four-inch plate		
5% prestrain + 1 hr at 550° F		
Center, 1/4 thickness	115	155
Center, mid-thickness	105	140

Kinzel tests

(1% lateral contraction transition temperature, °F)

	As-received	*Welded*	*Welded and stress relieved*
One-inch plate	−120	−30	−30
Four-inch plate			
1 in.—1/4 and 3/4 thickness	−95	5	−20
Full thickness	−100	−10	−60

Underbead cracking tests

	Cracking, %
One-inch plate	0
Four-inch plate	
Top surface (2-in. thick spec.)	0
1/4 thickness (2-in. thick spec.)	0
Mid-thickness (2-in. thick spec.)	0
3/4 thickness (2-in. thick spec.)	0
Bottom surface (2-in. thick spec.)	0
Top surface—Full thickness	0
Bottom surface—Full thickness	0

* Specimens parallel to rolling, notch in thickness direction.

Table 4—Test Data on A302 Steel

Location	Tensile properties: 0.2% offset yield strength, psi	Tensile strength, psi	Elongation, %	Reduction in area, %
Full-section tension tests (room temperature)				
4-in. full section	66,500	88,400	20.1	49.0
	66,100	88,100	21.8	55.2
4-in. longitudinal—0.505's	62,800	86,100	25.5	63.8
1-in. full section	52,000	83,300	22.1	55.8
0.505-in. tension tests—room temperature				
One-inch longitudinal	54,000	89,500	23.2	56.6
Four-inch longitudinal				
Center, 1/4 thickness	65,300	89,600	25.0	63.8
	68,400	91,700	24.5	62.6
Center, mid-thickness	59,500	83,100	26.0	64.6
	64,300	87,400	25.0	60.1
Edge, 1/4 thickness	62,600	85,700	25.5	65.1
	66,900	89,500	23.5	64.3
Edge, mid-thickness	56,600	80,300	28.0	64.3
	58,100	82,000	26.5	65.3
One-inch transverse	53,800	90,500	21.5	50.3
Four-inch transverse				
Center, 1/4 thickness	64,300	88,600	23.0	56.1
	65,300	89,500	22.0	55.1
Center, mid-thickness	59,100	83,000	24.0	56.1
	60,000	83,900	22.5	54.4
Edge, 1/4 thickness	65,700	89,500	21.5	55.9
	66,400	89,300	21.5	57.1
Edge, mid-thickness	58,500	82,300	24.5	54.9
	57,500	81,000	24.5	54.7
0.505-in. tension tests—550° F				
One-inch transverse	52,300	96,200	16.5	31.0
Four-inch transverse				
Center, 1/4 thickness	60,300	87,900	19.5	49.5
	54,100	83,600	18.5	48.0
Center, mid-thickness	50,700	78,400	20.0	47.6
	58,100	84,400	18.5	47.5

Location	Cantilever beam fatigue tests: Allowable strain range at 100,000 cycles, %
Three-quarter inch plate (tensile strength, 87,300 psi)	0.53
Four-inch plate	
Center, 1/4 thickness	0.52
Center, mid-thickness	0.51

Location	Charpy V-notch tests*: 15 ft-lb transition temperature, ° F	50% fibrous fracture transition temperature, ° F
One-inch plate	−15	+20
Four-inch plate		
Center, 1/4 thickness	−60	+80
Center, mid-thickness	−65	+45
Edge, 1/4 thickness	−85	+35
Edge, mid-thickness	−70	+25
One-inch plate		
5% prestrain + 1 hr at 550° F	+65	...
Four-inch plate		
5% prestrain + 1 hr at 550° F		
Center, 1/4 thickness	−15	+80
Center, mid-thickness	−15	+60

Kinzel tests

(1% lateral contraction transition temperature, °F)

Location	As received	Welded	Welded and stress relieved
One-inch plate	−80	20	−95
Four-inch plate			
1 in.-1/4 and 3/4 thickness	−155	75	−60

Location	Underbead cracking tests: Cracking, %
One-inch plate	58
Four-inch plate	
Top surface (2-in. thick spec.)	24
1/4 thickness (2-in. thick spec.)	45
Mid-thickness (2-in. thick spec.)	46
3/4 thickness (2-in. thicks spec.)	51
Bottom surface (2-in. thick spec.)	17
Top surface—Full thicknes	26
Bottom surface—Full thickness	23

* Specimens parallel to rolling, notch in thickness direction.

Table 5—Test Data on Navy G Steel

Tensile properties

Location	*0.2% offset yield strength, psi*	*Tensile strength, psi*	*Elongation, %*	*Reduction in area, %*
Full-section tension tests (room temperature)				
4-in. full section	104,800	116,000	20.1	53.6
	106,000	116,300	20.8	57.2
4-in. longitudinal—0.505's	108,000	118,000	20.5	65.3
1-in. full section	76,700	92,800	19.5	64.6
0.505-in. tension tests—room temperature				
One-inch longitudinal	81,200	97,200	22.2	70.0
Four-inch longitudinal				
Center, 1/4 thickness	108,000	117,400	20.0	64.0
	107,600	117,900	21.5	65.7
Center, mid-thickness	107,000	118,000	20.5	64.5
	108,000	118,300	21.0	66.0
Edge, 1/4 thickness	109,000	118,400	20.5	65.5
	108,000	118,100	20.5	65.3
Edge, mid-thickness	108,000	118,000	20.0	65.7
	108,000	119,000	20.0	66.0
One-inch transverse	82,600	97,000	22.8	71.1
Four-inch transverse				
Center, 1/4 thickness	113,000	119,000	18.5	57.3
	112,500	119,000	19.0	57.3
Center, mid-thickness	107,000	118,200	19.5	60.0
	106,000	117,800	20.5	58.5
Edge, 1/4 thickness	108,000	118,800	19.5	59.5
	108,000	118,500	16.5	59.2
Edge, mid-thickness	108,800	119,400	18.0	54.9
	108,500	119,600	18.0	54.0
0.505-in. tension tests—550° F				
One-inch transverse	72,000	91,700	20.8	59.4
Four-inch transverse				
Center, 1/4 thickness	97,500	112,800	15.5	48.3
	97,500	112,000	17.5	52.3
Center, mid-thickness	96,500	112,800	17.0	47.7
	99,500	114,900	15.5	42.8

Cantilever beam fatigue tests

Location	*Allowable strain range at 100,000 cycles, %*
Three-quarter inch plate (tensile strength, 95,200 psi)	0.56
Four-inch plate	
Center, 1/4 thickness	0.70
Center, mid-thickness	0.69

Charpy V-notch tests*

	15 ft-lb transition temperature, ° F	*50% fibrous fracture transition temperature, ° F*
One-inch plate	−80	...
Four-inch plate		
Center, 1/4 thickness	−20	+160
Center, mid-thickness	−15	+160
Edge, 1/4 thickness	−30	+145
Edge, mid-thickness	−20	+140
One-inch plate		
5% prestrain + 1 hr at 550° F	+10	...
Four-inch plate		
5% prestrain + 1 hr at 550° F		
Center, 1/4 thickness	+30	+170
Center, mid-thickness	+30	+180

Kinzel tests

(1% lateral contraction transition temperature, °F)

	As-received	*Welded*	*Welded and stress relieved*
One-inch plate	−210	−50	0
Four-inch plate			
1/4 thickness	−60	+100	−5
3/4 thickness	−80	+100	−20

Underbead cracking tests

	Cracking, %
One-inch plate	2
Four-inch plate	
Top surface (2-in. thick spec.)	0
1/4 thickness (2-in. thick spec.)	6
Mid-thickness (2-in. thick spec.)	2
3/4 thickness (2-in. thick spec.)	2
Bottom surface (2-in. thick spec.)	0
Top surface (full thickness)	0
Bottom surface (full thickness)	1

* Specimens parallel to rolling, notch in thickness direction.

Table 6—Test Data on T-1 Steel

Tensile properties

Location	0.2% offset Yield strength, psi	Tensile strength, psi	Elongation, %	Reduction in area, %
Full-section tension tests (room temperature)				
4-in. full section	91,600	104,800	22.8	57.8
	91,900	105,700	23.5	58.1
4-in. longitudinal—0.505's	90,600	106,000	22.6	68.0
1-in. full section	114,000	123,600	13.9	57.5
0.505-in. tension tests—room temperature				
One-inch longitudinal	111,000	122,000	17.8	62.2
Four-inch longitudinal				
Center, 1/4 thickness	90,400	105,000	23.0	67.6
	90,800	105,900	22.0	66.8
Center, mid-thickness	90,400	105,100	23.0	69.5
	92,600	107,200	21.5	67.0
Edge, 1/4 thickness	87,800	103,300	24.0	69.0
	91,000	105,200	22.5	67.0
Edge, mid-thickness	91,000	108,000	21.5	67.4
	90,400	104,200	23.0	68.5
One-inch transverse	110,800	118,700	17.0	57.6
Four-inch transverse				
Center, 1/4 thickness	93,400	107,000	21.0	59.4
	91,400	105,100	21.0	60.4
Center, mid-thickness	91,600	105,300	22.5	61.8
	91,900	105,900	22.0	60.2
Edge, 1/4 thickness	90,800	105,300	22.0	63.3
	90,400	105,300	23.0	61.9
Edge, mid-thickness	90,800	104,600	23.0	65.0
	90,100	104,300	22.0	64.0
0.505-in. tension tests—550° F				
One-inch transverse	103,000	118,300	15.2	47.0
Four-inch transverse				
Center, 1/4 thickness	79,700	99,100	19.0	49.2
	78,200	96,200	16.0	50.7
Center, mid-thickness	80,400	101,000	16.5	45.2
	76,500	94,700	18.0	50.0

Cantilever beam fatigue tests

Location	Allowable strain range at 100,000 cycles, %
Three-quarter inch plate (tensile strength, 130,000 psi)	0.61
Four-inch plate	
Center, 1/4 thickness	0.58
Center, mid-thickness	0.59

Charpy V-notch tests*

	15 ft-lb transition temperature, ° F	50% fibrous fracture transition temperature, ° F
One-inch plate	−195	...
Four-inch plate		
Center, 1/4 thickness	−80	+25
Center, mid-thickness	−60	+65
Edge, 1/4 thickness	−85	+45
Edge, mid-thickness	−80	+50
One-inch plate		
5% prestrain + 1 hr at 550° F	−160	...
Four-inch plate		
5% prestrain + 1 hr at 550° F		
Center, 1/4 thickness	−25	+60
Center, mid-thickness	+10	+110

Kinzel tests

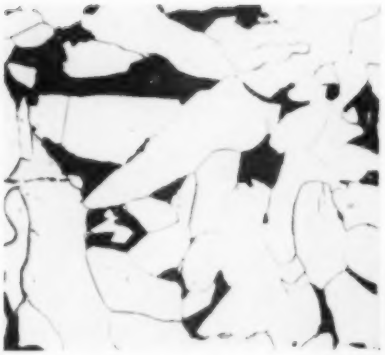
(1% lateral contraction transition temperature, °F)

	As-received	Welded	Welded and stress relieved
One-inch plate	−225	−80	−90
Four-inch plate			
1 in.—1/4 and 3/4 thickness	−150	−30	−20

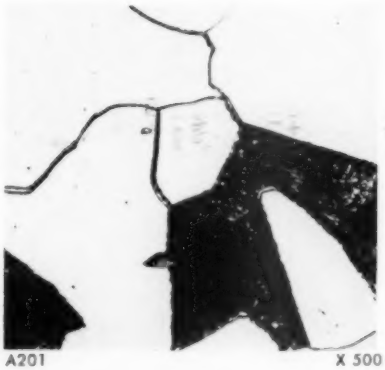
Underbead cracking tests

	Cracking, %
One-inch plate	39
Four-inch plate	
Top surface (2 in. thick spec.)	21
1/4 thickness (2-in. thick spec.)	22
Mid-thickness (2 in. thick spec.)	24
3/4 thickness (2 in. thick spec.)	18
Bottom surface (2 in. thick spec.)	19
Top surface (full thickness)	15
Bottom surface (full thickness)	11

* Specimens parallel to rolling, notch in thickness direction.



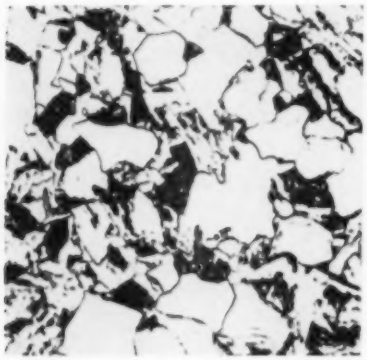
A2..1 X 100



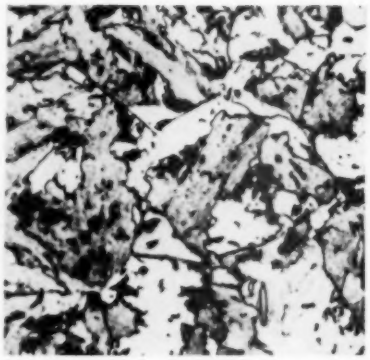
A201 X 500

Fig. 1 Typical microstructures of heavy section steels

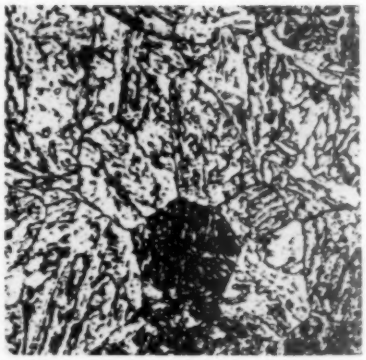
(Picral-nital etch)



A302 X 500



Navy G X 500



T-1 X 500

The specimens were 3 in. wide, 4 in. thick and 24 in. long, tested on a 22-in. span. The heavy specimens showed about a 30° F lower transition temperature than the 1-in. thick specimens from the same plate.

Results of standard underbead cracking tests with E6010 electrodes at 70° F on the steels are also presented in Fig. 10. The heavy-section plates were equally or less susceptible to cracking than the 1-in. plates. The effect of thickness position was negligible in all steels except A302. In this steel the surface showed considerably less sensitivity to cracking than the interior, possibly due to decarburization introduced during manufacture.

Fatigue Properties

Previous investigations have demonstrated the dependence of fatigue life on tensile strength. In Fig. 11 this relation is plotted for both $^3/_4$-in. plate specimens rolled from the same heat as the 1-in. high-strength steel plate and for $^3/_4$-in. specimens cut from the quarter-thickness and mid-thickness positions in the 4-in. plate. The allowable strain range for 100,000-cycle life was previously adopted as the most significant level at which to evaluate fatigue resistance for pressure-vessel applications. At this level the strain range varied linearly with tensile strength as previously reported for the $^3/_4$-in. plate. A201 in the 4-in. plate and T-1 in the $^3/_4$-in. plate evidenced some departure from the curve. The difference between quarter-thickness and mid-thickness values in the 4-in. plate was negligible. These values were averaged and a single point plotted

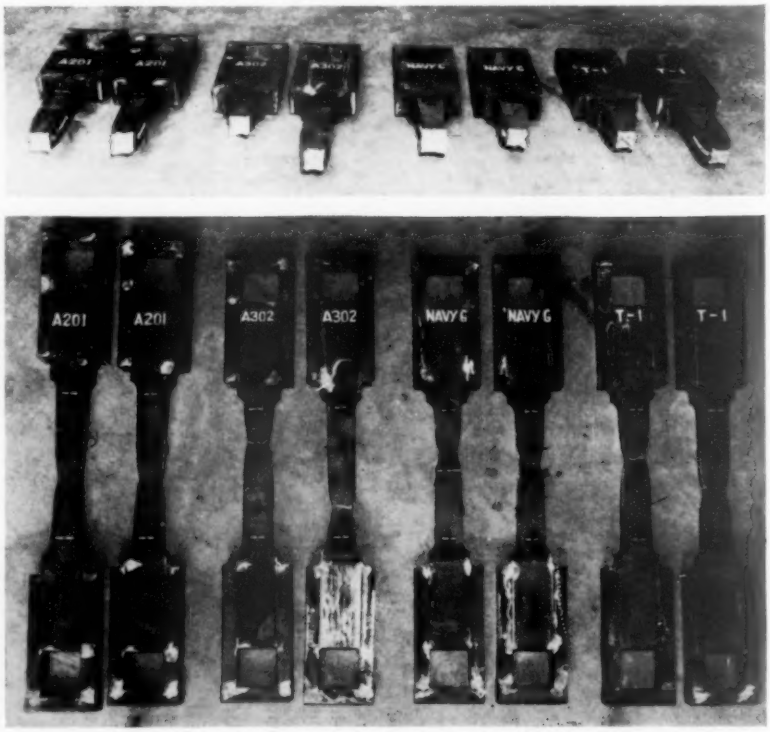


Fig. 2 Photographs of fractured full-section tension specimens

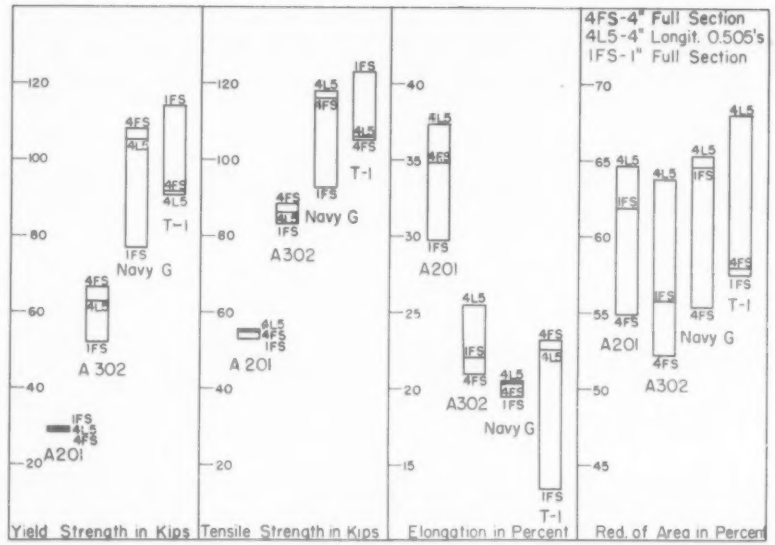


Fig. 3 Comparison of tensile properties of 4-in. full section, 4-in. longitudinal 0.505, and 1-in. full section specimens

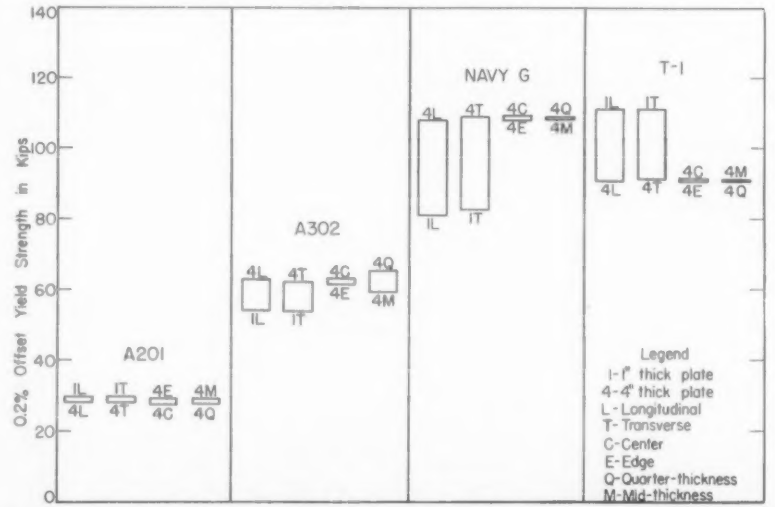


Fig. 4 The effect of plate position and thickness on the yield strength of 0.505-in. specimens

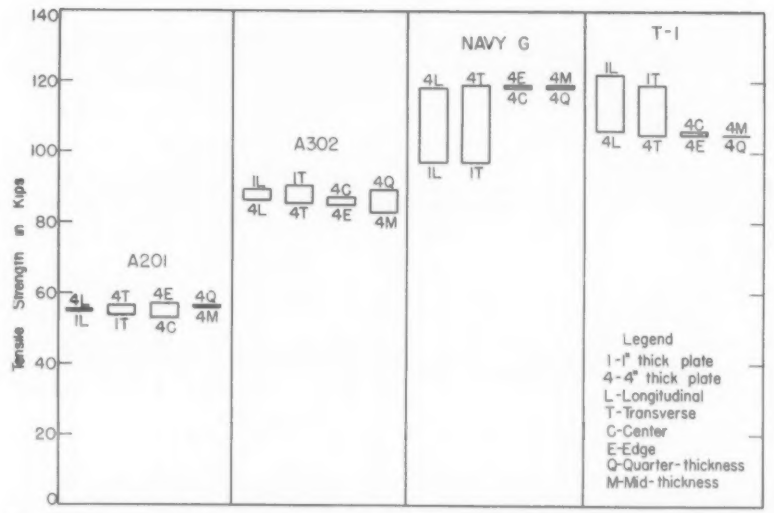


Fig. 5 The effect of plate position and thickness on the tensile strength of 0.505-in. specimens

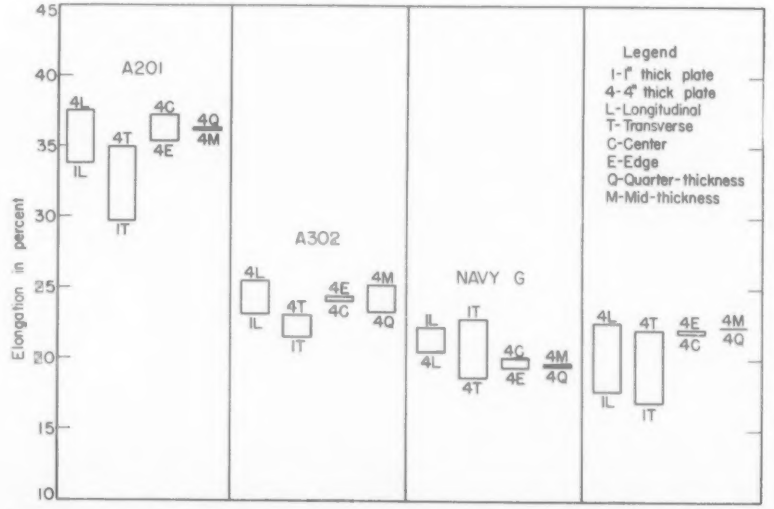


Fig. 6 The effect of plate position and thickness on the elongation of 0.505-in. specimens

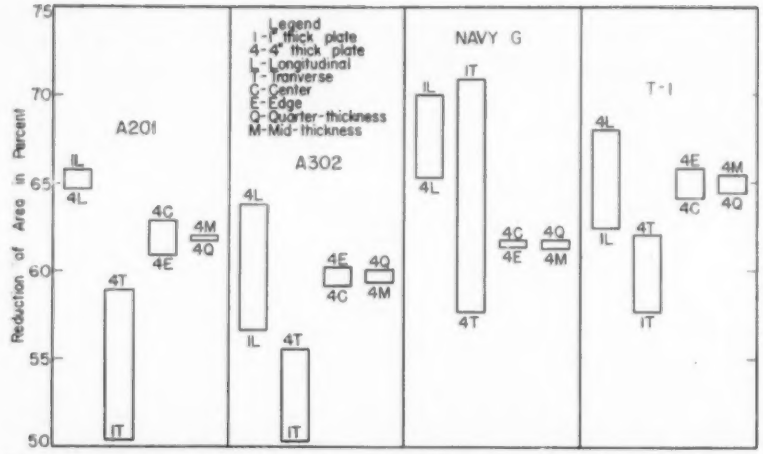


Fig. 7 The effect of plate position and thickness on the reduction of area in 0.505-in. specimens

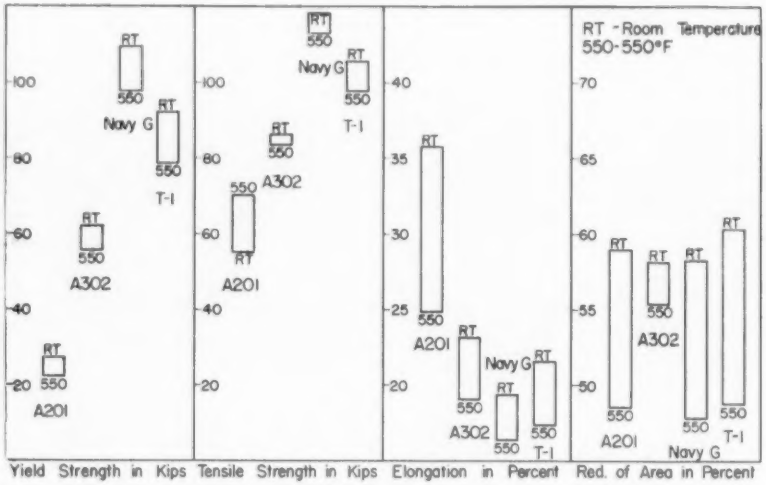


Fig. 8 The effect of elevated testing temperature on the tensile properties of transverse, 0.505-in., heavy-section specimens

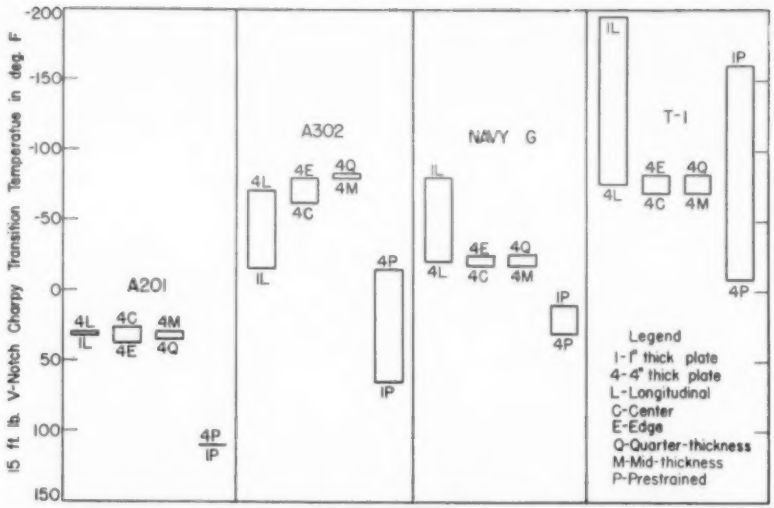


Fig. 9 The effect of plate position, plate thickness and strain aging on notch toughness

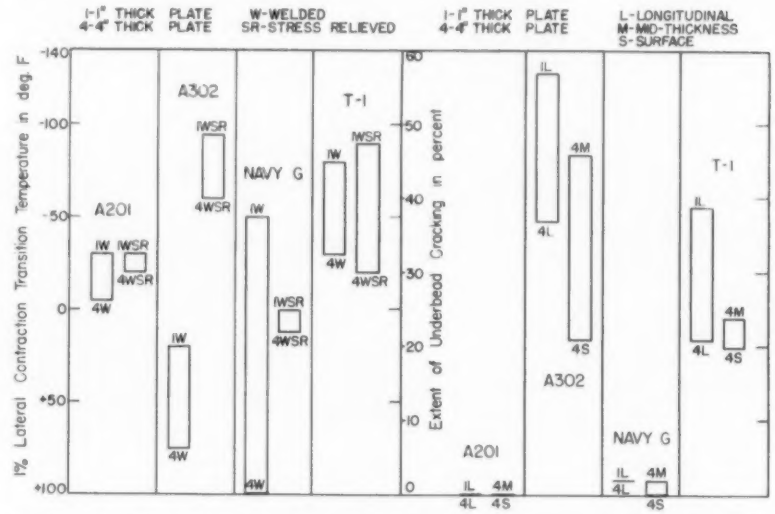


Fig. 10 (a) The effect of welding and stress relieving on notch toughness of 1- and 4-in. plate. (b) The effect of plate position and thickness on underbead cracking

for each heavy-section steel.

General Discussion

In general there appears to be no substantial difference in properties due to plate position either in the width or thickness dimension of the heavy-section steels. Good agreement was observed between small specimens cut from the thick section and full-size specimens. The principal differences existed between 1-in. plate values and 4-in. plate values. It is difficult to estimate the extent to which thickness alone influenced these results. It must be remembered that each thickness represented a different heat of steel thus introducing the variations that arise from heat to heat. One basis of comparison for the structure-sensitive properties would seem to be microstructure. Unfortunately, the effects of microstructural variables on mechanical properties are established only on a qualitative basis. However, a few comments can be offered in this connection. A201 steel was made to a coarse-grained practice. The larger ferrite grain size present in the 4-in. plate would be expected to reduce notch toughness properties. A302 was made to a fine-grained practice in the 4-in. section in order to improve low-temperature properties. This, together with stress relieving applied only to the 4-in. plate, probably accounts for the superiority of the 4-in. plate with respect to ductility and notch toughness. Navy G steel microstructures exhibited a greater amount of bainite in the 4-in. section than in the 1-in. section. This may account for the increased strength and decreased ductility and notch toughness. There is evidence of bainite in the 4-in. T-1 microstructure. This may be expected to reduce the tensile strength of the martensite and raise the transition temperature as was noted. These observations are based on rather superficial microexamination and could be documented only by more careful study.

Conclusions

In broad summary, the results of the investigation are as follows:

1. The 0.505-in. tensile properties differed appreciably only between the 4- and 1-in. thicknesses of Navy G steel and T-1 steel. No important variations were observed in any of the steels among locations in the 4-in. plate.

2. The 4-in. full-section tensile properties are very similar to the 0.505-in. values except for a loss in ductility introduced by the difference in specimen geometry.

3. In elevated-temperature tensile tests, A201 steel showed considerable strain aging as evidenced by an increase in tensile strength and loss of ductility. The loss in ductility was relatively less for the higher-strength steels. The two thicknesses of plate behaved similarly in all of the steels.

4. In the V-notch Charpy test, A201 was the least tough of the steels tested. The effect of plate position was negligible for all steels. The change from 1- to 4-in. plate improved the notch toughness of A302, lowered the notch toughness of Navy G and T-1, while A201 was essentially unchanged.

5. The 4-in. steels had welded notch toughness inferior to that of the 1-in. steels. Stress relieving brought the four heavy-section steels to more nearly the same level of transition temperature. The 4-in., full-section Kinzel tests on A201 developed a moderately lower transition temperature in all conditions than the 1-in. A201 specimens cut from the quarter-thickness position. There appears to be no advantage to testing full-section Kinzel specimens in plate as heavy as this.

6. Underbead cracking was appreciable only in A302 steel and T-1 steel. This cracking tendency was considerably less in the 4-in. plates. The surface of A302 steel tended to crack less than the mid-thickness possibly due to surface decarburization during mill processing.

7. The plastic fatigue strengths of the four steels are approximately proportional to their tensile strengths. Only the 4-in. A201 and the 1-in. T-1 deviated significantly from this relationship.

8. No appreciable variation in hardness or microstructure was detectable through the thickness of the 4-in. steels. Exhaustive study would be required to establish the relationship of properties to microstructure.

Table 7—Brinell Hardness Survey of Heavy-Section Steels

Distance below top surface, in.	*Steel A201*	*A302*	*Navy G*	*T-1*
1/2	109	189	253	218
1	107	191	255	219
1 1/2	105	187	257	219
2	103	185	256	215
2 1/2	107	191	257	226
3	106	191	259	226
3 1/2	112	189	259	231

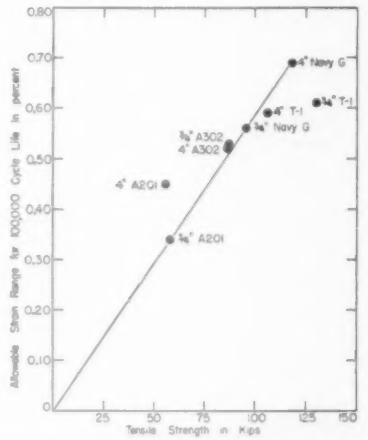


Fig. 11 The dependence of fatigue life on tensile strength

Reference

1. Gross, J. H., and Stout, R. D., "The Performance of High-Strength Pressure Vessel Steels," The Welding Journal, 35 (3), Research Suppl., 115-s to 119-s (1956).

PAPERS AT THE FOURTH CZECHOSLOVAKIAN WELDING CONFERENCE, 1954

(Continued from page 150-s)

welding electrodes. A particularly good composition is 90% W, the remainder being copper and nickel. Tungsten double carbide W_2C or its eutectic with WC is used for hard facing. (2) The use of iron powder as a welding and cutting material. For cutting cast iron and stainless steel the powder should consist of smooth particles 0.0024–0.006 in. in diameter. Iron powder for electrode coatings should meet the specifications: 0.10% C max, 0.50% Mn max, 0.10% Si, 0.03% S, 0.03% P and traces of Al and Cu.

Paper No. 7. "The Designer and Weldability," by F. Faltus. This paper discusses design considerations involving open arc and submerged arc welding of mild steel, particularly for bridges. Brittle failure is to be feared if there are hot cracks in the welds or if shrinkage stresses are severe. Brittle fractures can be avoided by reducing restraint, using thin sections, avoiding sharp notches, avoiding high shrinkage stresses and using killed steel instead of semikilled.

Paper No. 8. "Fatigue Strength of Submerged Arc Welded Plate Girders," by O. Puchner. Experiments were performed to ascertain the fatigue strength of plate girders welded by the submerged-arc process, to estimate the reduction in fatigue strength caused by moisture porosity and to evaluate efforts to repair the defective welds. The girders consisted of a web plate $8^1/_4$ in. deep, 0.67 in. thick welded to two flanges $5^1/_8$ in. wide, $1^1/_4$ in. thick. The throat of the weld was $^3/_8$ in. The beams were tested in four point loading, the loads being 8 in. apart and the span 4 ft. The web plates were not beveled. The girders were welded at the Mostaren Brezno Bridge Co., at 750 amp, 36 v, 24 ipm. Two mild steels (52,000 psi tensile strength) were used. One steel had low, the other high, notch impact value. All in all 22 girders were tested using a 220,000-lb Amsler pulsator at 250 or 500 cpm. The criterion of fatigue strength was 2 million cycles. The lower stress in all tests was 2800 psi.

The welded girders of both steels having no weld defects had the same fatigue strength (2800 psi lower stress, 32,800 psi upper stress) which was the same as unwelded I beams of these steels. The fatigue strength was lowered 30% by porosity. Fatigue failures originated at the porosity. Repair of porous areas by manual arc welding restored full fatigue strength. Small surface defects caused by careless fabrication practices lowered the fatigue strength up to 25%.

VOL. 2. *Paper No. 9.* "The Physics of Pressure Welding," by F. Erdmann-Jesnitzer. Pressure welding is shown to obey the same laws as the sintering of metal powders. Model tests on copper and sodium chloride crystals illustrate the transfer of material that accounts for both hot and cold pressure welding.

Paper No. 10. "Surfacing Tools with Ledeburitic Chromium Steel," by B. Zorkoczy. Best results in building up worn tools in Hungary have been obtained with a surfacing material containing 1.8–2.2% C, 11.5–14% Cr. The deposited metal is 62 to 64 C Rockwell. For plain carbon tools preheating to 1100–1200° F is recommended. High-alloy tool steels should be preheated to the austenite temperature.

Paper No. 11. "The Theoretical Basis for Classifying Welding Information," by Z. Dobrowolski. A system different from the Dewey Decimal System is proposed.

Paper No. 12. "Maintaining Quality under High Production Welding Conditions," by J. Prudky. Close cooperation among steel producer, fabricator and laboratory is required.

Paper No. 13. "The Fatigue Strength of Welded Joints," by J. Nemec. The importance of notches in fatigue is emphasized.

Paper No. 14. "The Cause of the Failure of a Welded Railway Bridge of 39 ft Span," by O. Puchner. The bridge consisted of four all-welded plate girders, each 23 in. high. In December 1951, after three years of service, three of the four girders broke in two. A number of cracks originating at the web-flange welds were found in the broken girders by magnetic-particle inspection. The cracks were found to originate at machining marks caused by a dull tool on the web plate. Under fatigue stress and shrinkage stress these machining marks became cracks spreading into the web. The final failure was a brittle crack passing through the rimmed steel of which flange and web were made.

VOL. 3. *Paper No. 15.* "Resistance Welding of Concrete Reenforcing Bars," by V. Gregor. For the past two years the Welding Research Institute of Bratislava has been engaged in a study of the resistance welding of reenforcing bars. A cross weld specimen was found to be a practical means of estimating the suitability of shipments of bars for resistance welding.

Paper No. 16. "An Instrument for Hardness Testing at Temperatures up to 1470 F," by L. Muncner. An impact hardness tester is described.

Paper No. 17. "The Theory of Diffusion of Heat in Submerged Arc Welding," by A. Havalda. Temperatures at a number of points were measured oscillographically during the submerged arc welding of single beads on steel plates $^1/_2$ in. thick at 26 ipm at 500, 600 and 700 amp and, at 600 amp, 19, 26 and 31 ipm. Five three-dimensional plots of the results are given.

Paper No. 18. "New Electrodes for Increased Productivity," by A. Kleander. The use of contact and deep penetration electrodes is described. The electrodes pass radiographic, face bend and T fillet bend tests.

Paper No. 19. "The Weldability of Plain Carbon Structural Steel," by J. Lombardini. The notch impact survey recommended in Paper No. 1 is shown to be a satisfactory basis for estimating weldability.

the weldor's favorite redhead!

TWECO GROUND CLAMP

Made in Four Sizes

TWECO, the original arc welding ground clamp, provides a quick, positive and portable connection to the work. The entire welding circuit, including the electrode holder, runs cooler with a Tweco ground clamp, which helps to eliminate arc blow, slides on and off the work easily, yet provides a firm bite on the work with ample contact area in either or both jaws. Order from your welding distributor now to enjoy this positive grounding which makes possible lower machine settings, reducing current consumption and power costs.

SEE YOUR LOCAL WELDING SUPPLY DISTRIBUTOR

Write for FREE Catalog picturing complete line of Arc Welding Accessories and TWECO-LITE Aluminum Arc Welding Cable.

Tweco

MANUFACTURERS: ARC WELDING ELECTRODE HOLDERS, GROUND CLAMPS, CABLE CONNECTORS, TWECO-LITE ALUMINUM WELDING CABLE

PRODUCTS, INC.

BOSTON AT MOSLEY • WICHITA, KANSAS, U.S.A.

Another first to help widen the scope of welding

Opens up new standards of speed and economy in welding mild steel

Here's the first all-position class 6010 electrode ever made with an iron powder coating. X-Ray and physical properties of the new Easyarc 10 are excellent. Outstanding characteristics for all-position welding with the inherent advantages of an iron powder coating. For a free sample of the new Easyarc 10, contact your nearest Airco Office.

AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND . . .

AIR REDUCTION SALES COMPANY

A division of Air Reduction Company, Incorporated, New York 17, N. Y.

AIRCO®

Offices and dealers in most principal cities

VISIT OUR BOOTH 334 WELDING SHOW

APRIL 9-11, 1937 · PHILADELPHIA, PA.

On the west coast — Air Reduction Pacific Company

Internationally — Airco Company International

In Cuba — Cuban Air Products Corporation

In Canada — Air Reduction Canada Limited